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THE "ASTRONOMER'S" GLOBE.

A. E. DOUGLASS.

FOR POPULAR ASTRONOMY.

The accompanying plate presents a view of a globe so mounted that spherical triangles of any dimensions can be solved graphically upon it to within half a degree, or less, of the correct result. The sphere itself is the ordinary commercial globe carried to the stage that precedes the fastening on of map, and has the ends of the axis removed. The finish is hard and smooth and lead pencil marks may be erased from it with a hard rubber and ink may be taken out by powdered pumice and leather. The globe represented in the photograph is twelve inches in diameter.

The base of the mounting is a circular piece of wood 16 inches in diameter and is supported on three small feet. Over the feet are three uprights supporting a wooden "horizon plane" passing round the horizontal circumference of the globe. Each upright has an adjustable point projecting inward from it; upon these three points the globe rests and therefore becomes adjustable in any direction. Upon the horizon plane two concentric graduated circles of brass move freely; the plane of the upper surface of these circles intersects the globe through its center. Each circle is hinged at points 180 apart, so that the two semicircles thus made in each, can fold together. The accuracy of work upon the globe depends largely upon the excellence of figure and graduation of these circles and with more care in that particular the results of work upon a twelve inch globe might easily be relied upon to with one-tenth of a degree.*

By proper adjustment of the semi-circles it becomes possible to place any kind of a spherical triangle of sufficient magnitude upon the globe and thus to solve graphically, to a limited degree of accuracy, any problem in spherical trigonometry. It has the advantage of all graphic solutions that the main conditions of the problem are presented to the eye and thus mistakes are less likely to occur than in using "soulless" formulas. In many operations it is far more direct and rapid than a mathematical solu-

* The cost of the entire globe and mounting as described above and a box for holding it, was under twenty-five dollars.

tion, is sufficiently accurate for the class of observations and offers a better means of estimating the value of the final results. In illustration of this statement the following paragraphs are added in order to indicate some of the uses to which it may be put and the general methods of operating it. In each case the globe is supposed to be ruled with meridians and parallels ten degrees apart, the equator and occasional meridians further marked to degrees and the semicircles, of course, graduated accurately to degrees, the end of each being marked 0 and its center 90.

Sunspot Work.— For the work necessary in followiug the movement of sunspots the horizon plane of the globe indicates the apparent limb of the Sun, the graduation on the globe represents heliocentric longitude and latitude and the apex or "centre" of the globe is set at the longitude and latitude of the Earth. This is done by raising two semicircles into the exact vertical position so that they intersect at right angles; their point of intersection will be the apparent centre of the Sun or the apex of the globe. As measurements upon the Sun are made from north and south, or east and west lines it is necessary to know these directions on the globe. That is easily done, it being only necessary to mark once for all the positions in longitude and latitude occupied by the poles of the Earth. Passing, therefore, one vertical semicircle through the apex and one of these poles, and the other semicircle at right angles to the first, they are ready to plot the position of the spot. The distance of the spot from the rectangular coördinates is then measured in terms of a radius and reduced directly to degrees; the corresponding degree mark is then selected on each semicircle and the two points brought into coincidence; the point on the globe beneath this intersection will be the position of the spot expressed in longitude and latitude.

If it is assumed that the pole of the Sun is known then let the meridians and parallels of the globe represent soligraphical positions; plot and graduate the ecliptic with reference to this solar longitude and latitude and mark as before the position of the poles of the Earth. By these means the centre of the globe may be set and the circles oriented and adjusted as before and the position of the spot on the Sun read off at once.

This method not only enables the observer to reduce his work with great rapidity and judge at once of the general agreement of his observations but also anything of peculiar character which ought to be more carefully observed, will immediately attract his attention. This process applies equally well to visual or photographic measurements. If in any measurement one coördin-

ate is in error, it will be at once apparent and the other coördinate remains good and may be plotted upon the globe and be of value, so that the observation is by no means wholly lost.

Terrestrial Work.—Right ascension and declination may be turned into longitude and latitude, or the reverse, roughly, but with all the accuracy required, for instance, by Gegenshein or Zodiacal Light observations. For this operation either a horizontal or vertical pole may be used and the globe and circles may represent respectively right ascension and declination and longitude and latitude, or the reverse, as found most convenient. For an example, we might set the centre of the globe at the right ascension and declination of the north pole of the ecliptic, the graduation of the globe itself representing right ascension and declination; the horizontal semicircles will then give longitude and the vertical semicircles, latitude. By this setting, also, the relative effect of precession in different parts of the sky may be obtained directly.

Transposition may also be affected between altitude and azimuth and right ascension and declination, and also, by considering the coördinate on the globe to be longitude and latitude and adding the celestial pole and equator, the transposition may be carried directly from altitude and azimuth to longitude and latitude. As always, the solution is rough and is useful as a check, or in preliminary reductions. In these instances the globe will, of course, give the celestial coördinates and its apex be set at the latitude of the place and the sidereal time; the circles will measure altitude and azimuth.

This use of the globe will perhaps be especially valuable in such work as determining directions of motion of a star with reference to altitude and azimuth, or the displacement in celestial position produced by refraction. Such a problem as this can be solved with ease:—What is the effect of refraction upon measurements of polar and equatorial diameters of a planet. In this the most natural method is to set the centre at the sidereal time and latitude of the place. A vertical semicircle will give the altitude and the parallactic angle may be marked and measured at once by a special sector arranged for the purpose, or afterward by changing the position of the globe. In the absence of such a sector the distinctly better plan is to proceed as follows for each observation: Let the globe coördinates represent stationary celestial positions with both the pole and planet in the horizon plane. Set the joint of one of the circles over the position of the planet and place the other circle at right angles to this one, with half of

it raised to the upright position for measuring the parallactic angle. Then let the zenith be the movable point and locate it for each observation by means of its right ascension and declination. Pass the first upright semicircle through this zenith point and read off from it the zenith distance, and from the other semicircle the parallactic angle. For reducing many observations it is best to draw a line which represents the motion of the zenith, and graduate it. It will then serve for all reductions of this character at a given Observatory. Of course the parallactic angle needs to be further corrected by the position angle in which the measurements were made; the effect of refraction upon the vertical diameter of the planet at the altitude determined may then quickly be reduced to its lesser effects in the direction used.

If it is desired to work out even this latter reduction on the globe it may be done with great precision as follows: The effect of refraction, except near the horizon, is to change a circle into an approximate ellipse. Incline the pole of the globe far enough from the apex so that the difference between the projection of the equator and the equator itself, represents the effect of refraction upon the form of a circular planet. This inclination takes place in a direction representing the vertical, and unity minus the cosine of its amount represents the effect of refraction on the vertical radius. Now turn one of the circles so that its pole, that is, a line joining its hinges, represents the direction of measurement and swing one half of it into an upright position and by testing measure the distance from the hinge to the nearest point on the equator of the globe. The horizontal projection of this nearest point is the projection of the one actually used in measurement and unity minus the cosine of the distance is the effect of refraction on the radius measured. By this process the effect of the elliptical form is fully taken into account. In case the planet itself is not circular we may consider the diameter of the globe to represent, for instance, its polar diameter; the effect of refraction upon the equatorial diameter will then have to be made proportionate to its size.

These processes thus far have been described in considerable detail to render more clear the use of the globe and to draw attention to the fact that there are often several methods of solution, one of which may be much more practicable than the others.

Planetary Work Exemplified by Work on Mars.—It was for the solution of many problems occurring in work on Mars that the globe was originally invented and constructed and it has been used in all those processes mentioned below. It is therefore spe-

cially adapted to that grade of accuracy and available for many different operations, and whatever use it has here may similarly be found applicable to work on other planets though in varying degrees.

The first application is in correctly reproducing or comparing drawings and especially the portion of drawings more than half a radius distant from the centre. Owing to the distortion of markings seen in such regions large errors in position or identification are likely to occur unless the drawings are reproduced on the actual curved surface of a sphere. Personal experience with and without the globe has produced this opinion.

In such work on Mars the apex of the globe is set at the longitude and latitude of the centre as taken from the ephemeris and, if necessary, one of the semicircles is supported in an inclined position to represent the terminator. This of course is easily located from the angle between the true and phase poles and the angle of defect of illumination, that is, the phase angle.

Next, it may be used in determining the Areographical position of objects measured on the apparent disk by applying the methods already described under the subject of sunspots. The same advantages mentioned there apply here; no observation is lost through lack of the other coördinate and a good idea is at once obtained of the accuracy of the resulting position of a given point and of the individual observations.

Furthermore by marking roughly on each plotted latitude observation the Martian meridian distance at which it occurred, every point which received several observations at different places on the disk will give valuable data for determining the correctness of the position of the assumed pole.

It is evident that by the setting first described in connection with Mars the Areographical position of the cusps, terminator centres, and so forth, may be read off at once. Irregularities or other objects on the terminator whose locations were measured by the position angle of the adjacent portion of the terminator, may be readily solved by placing the pole of one circle at right angles to the recorded position angle and then finding the point on the terminator nearest the hinge of the circle. The coördinates of the point on the globe beneath this will be the required Areographical position.

The phase correction for a diameter measured in any given direction may be found by the method already described under the effect of refraction upon a planet's diameters. In fact observations upon the ellipse which involve tangents to the curve or the use of polar coördinates can be solved upon the globe.

In one other process of Martian work it is difficult to suggest any other method of solution. This is the plotting of canals or long marks whose position angles had been observed. With the globe it is necessary to set the apex at the Martian longitude and latitude at the time of observation and place the pole of one of the circles at right angles to the observed position angle and then choosing a point through which the canal runs, to hold a pencil against the upright semicircle and by swinging the semicircle backwards and forwards to produce a line of the given position angle. Of course sketches or other measurements must serve to indicate length and general location of this line. Position angles thus taken and plotted are a great help in map making by connecting together the many independent measurements of position.

Instruction.—It will not be amiss to suggest that this globe might be useful in class-room work by presenting graphically to pupils the actual operation involved in working out a set of formulas.

There are two appliances which will help its working, but which have hardly been mentioned because as yet they lack actual trial. One is a sector for measuring any angle occurring between the two upright semicircles and the other is a movable pin which serves to steady the lower invisible pole of the globe so that the globe may be turned on its axis and set more quickly for a succession of observations. For this purpose the ends of the steel bar passing through the globe should be bored to a depth of half an inch and a small pin for entering it arranged on the end of an arm attached to a sliding carriage. The carriage slides upon, and clamps to, a semicircle of slightly greater radius than the globe and passing beneath it and the purpose of the extended thin brass arm is to allow the pin to pass up between the globe and the horizon plane and circles and avoid interfering with the motions of the latter.

LOWELL OBSERVATORY, Mexico,
April 2, 1897.

THE ASTROGRAPHIC CHART.

F. W. DENNING.

The fourth *réunion* of the Comité Permanent was held in Paris in May. The reports furnished by the directors of the co-operating observatories show that satisfactory progress has been made

in two-thirds of them. Owing to political or financial difficulties the work has not yet begun at Santiago de Chili, La Plata and Rio Janeiro, and is seriously hampered at several other observatories.

The following table shows how far the photo-mapping has advanced in the different zones :—

	Zone.	No. of Fields Assigned.	No. taken for Cat.	Chart.	
Greenwich	+ 90 to + 65	1,149	728	472	213 plates measured; 102 plate constants determined.
Rome	+ 64 " + 55	1,040	280	100	—
Catania	+ 54 " + 47	1,008	21	None	—
Helsingfors	+ 46 " + 40	1,008	1,008	A few	160 plates measured and partly reduced.
Potsdam	+ 39 " + 32	1,232	500	"	35,000 stars measured.
Oxford	+ 31 " + 25	1,180	800	None	40,000 stars measured on 160 plates.
Paris	+ 24 " + 18	1,260	1,155	Not stated	318 plates measured, 60 reduced.
Bordeaux	+ 17 " + 11	1,260	300	60	Measures to be begun soon.
Toulouse	+ 10 " + 5	1,080	150	350	70 plates measured.
Algiers	+ 4 " − 2	1,260	1,000	64	168 plates measured with 32,000 stars.
San Fernando	− 3 " − 9	1,260	1,260	about 400	50 plates measured once and 25 twice.
Tacubaya	− 10 " − 16	1,260	529	not stated	Measuring to begin soon.
Santiago de Chili	− 17 " − 23	1,260	—	—	—
La Plata	− 24 " − 31	1,360	—	—	—
Rio Janeiro	− 32 " − 40	1,376	—	—	—
Cape of Good Hope	− 41 " − 51	1,512	1,512	Nearly half	30 plates measured.
Sydney	− 52 " − 64	1,400	1,393	1,112	—
Melbourne	− 65 " − 90	1,149	703	A few	—

Examination of this table shows that (omitting altogether the three South American Observatories which have not yet com-

menced) the taking of the catalogue plates is generally well advanced, and that some progress has been made with the chart plates. The measurement and reduction of the catalogue plates has been begun by more than half the observatories and considerable progress has been made by six or seven of them.

The Congress first turned its attention to the degree of accuracy which it was desirable to obtain in the measurement of the photographs. It was decided that the probable error of the measured coördinates ought not to exceed $\pm 0''.20$.

The choice of the reference-stars and the methods of measurement and reduction were left to the discretion of the directors of the coöperating observatories. It was resolved that the measured rectilinear coördinates should be published as soon as possible, along with the necessary data for obtaining the right ascension and declination of the stars when required. With regard to the magnitudes, the Congress laid down no conditions except that the methods adopted for their determination should be capable of precise definition, so that the scales employed at different observatories might be readily comparable. For the Chart it was decided that in the odd zones a triple exposure of 30^m should be given.

Captain Abney undertook to supply the different observatories with scales which should be printed on the plates at the same time as the *réseau*, and supply a measure of the sensibility of the plates for light of different intensities. It was also resolved that two positives of each chart-plate should be made on glass, and that one of them should be placed in the Bureau National des Poids et Mesures.

Several papers have appeared during the year, exemplifying the methods adopted at various observatories (*e. g.* Paris, Helsingfors, Greenwich) for the determination of plate-constants, and the accuracy which may be obtained from the measures on the catalogue plates.

It is our sad duty to record the death of the President of the Comité Permanent, M. Tisserand, the distinguished Director of the Paris Observatory.—*Monthly Notices of R. A. S.*, Feb. 1897.

ATMOSPHERE, TELESCOPE AND OBSERVER.

A. E. DOUGLASS.

FOR POPULAR ASTRONOMY.

It is a matter of importance and significance that so little has been done in recent years upon planetary detail by telescopes of

great size. The strenuous effort to produce instruments of enormous power and perfection has resulted in telescopes of remarkable light-giving capacity, which have a true motion and are all that could be desired in convenience, but which do not show improved definition. There is no difficulty at all in assigning poor atmosphere as the cause of this because with the exception of the Lick Observatory, the Harvard Observatory in Peru and the two stations of the Lowell Observatory no effort of any moment has been made to place large instruments in locations directly selected for their astronomical qualities.

The thirty-six inch of the Lick Observatory was in a sense the pioneer in this hunt for good surroundings but on account of the great size of the glass and the lack of comparison observations in even better latitudes it was impossible to estimate with any precision the relative importance of atmosphere and instrument.

The Harvard expedition to Peru was more successful. There, Professor W. H. Pickering, having at Cambridge, U. S. A., observed Mars through one opposition, was able to declare at once the superiority of the atmosphere. For the same reason he could indicate the difference between Cambridge and Flagstaff; the fact that for certain measurements of the satellites of Jupiter he habitually used a power of 1305 is sufficient evidence of the steadiness of the air at the latter place. Professor Pickering was unquestionably the first to intelligently appreciate the great importance of seeking a good atmosphere.

The result of our own experience in studying planetary detail has been to regard the atmosphere as of the first importance, the energy and the intelligence of the observer as of the second and to put last of all, the instrument, provided it gives a fair amount of light; but we find that the value of the instrument increases in an atmosphere that is reasonably near perfect. These conclusions are derived from the continuous use of large telescopes in Peru, Massachusetts, Arizona and Mexico.

The atmosphere then is a factor of prime importance in the definition exhibited by large telescopes and its study becomes of corresponding consequence. Every astronomer knows that good seeing is not a matter of clouds, that the definition does not become superb merely because the atmosphere has become clear and perfectly transparent; on the contrary a certain amount of haze sometimes improves the seeing. Most astronomers have become aware of this fact and more correctly judge the seeing by means of the "steadiness" of the air. This is estimated chiefly from the twinkling of stars. Hardly one or two have gone beyond this

and investigated the cause of twinkling and found the means for making direct observations upon the quality of the atmosphere for fine work.

There are three media through which the light from a distant heavenly body must pass before being interpreted by the students of astronomy. And upon each of these three, Atmosphere, Telescope and Observer, it is our purpose to make some remarks, describing certain details of each that have come under our observation. Through the discovery of certain methods of studying directly the conditions of the air for astronomical work and the vast importance of obtaining favorable conditions, the larger and more important portion of this paper is devoted to the description of the origin and character of those methods. Taken in its entirety this treatment of the three topics is introductory to the study of the selection of Observatory sites.

The Atmosphere; Its Currents.

Every posseesor of a fair sized telescope has at hand a means whereby he may study the more obscure atmospheric conditions which accompany good and bad seeing and, at least in some cases, determine whether bad seeing is due to local conditions which may be evaded by moving a few miles, or to general conditions which may require a large change in latitude to correct. The means consists simply in placing the eye directly in the focus of the objective and watching the streams of air pass by overhead.

These currents were first noticed in this way by the writer, at the Harvard College Observatory station at Arequipa, Peru, in 1892. That Observatory is situated on the bank of a canyon-like river valley which drains some large plains lying fifteen miles to the north and at some five thousand feet greater altitude. In the early night, if the sky is clear, the air becomes cold in the bottom of this valley and begins to flow gently downward. Soon it attains considerable velocity, spreading out over the more open valley below. Some hours after midnight its volume is such that it overflows its confines and submerges the Observatory producing a sudden lowering of temperature and an immediate destruction of the seeing.

The movement could be felt as a fresh steady, chilly breeze coming from the mountains to the north. By means of the objective it could be seen as a set of fine parallel north and south lines moving swiftly from north to south. This effect of lines moving longitudinally is of course the effect always produced by an uneven surface passing rapidly across a small field of view, as, for

example, the appearance of the ground between the rails when one stands on a swiftly moving train and looks down between the cars. The absence of any such appearance in the objective previous to the arrival of this midnight wind amply proved the the connection between these moving lines and the descending breeze.

This connection between the streams of air and lines across the objective was subsequently verified by an experiment tried on the great Yerkes lens when it was undergoing tests at Alvan Clark's manufactory. A lighted lamp held before the objective produced a very conspicuous series of them rising across the field. Any owner of a telescope can make a similar test by pointing on a star at low altitude and, while receiving the image of the star directly on the eye, having a lighted lamp or lantern held beyond the objective.

Beginning in September, 1894, the writer made observations upon atmospheric currents in the 18-inch Brashear lens at Flagstaff. It was found that the direction of the currents and roughly their heights and velocities could be obtained. This discovery seemed to chiefly concern meteorologists and the results of the observations up to the end of the following December were discussed with especial reference to that subject in an appropriate magazine (*American Meteorological Journal*, March, 1895). From January 1 to April 3, 1895, observations were made at Flagstaff on every clear night and the astronomical importance of such work became more apparent. Since that time observations have been made whenever practicable and tests on artificially produced currents have verified the conclusions already reached.

One of the most striking instances of the use of these observations, was the discovery of the reason why some of the east winds at Flagstaff gave good seeing and others bad. When the seeing was good the currents seen through the telescope came also from the east but when the seeing was bad they did not do so at all. Instead, they came from the north or northeast and the mountain range extending from ten miles due north to about six miles east, northeast was shown to be responsible both for the change of direction in the surface movement and the very bad quality of the stream which was passing by at considerable altitude overhead. It seems probable from this that neighboring mountain ranges are not good.

The examination of the atmosphere by means of a lens is nearly the same operation as the test of a lens for ascertaining its correctness of form. In the ordinary test on a bright star the expert

looks for the unchanging irregularities in the illumination of the objective; such irregularities belong to the objective because they are unchanging. In examining the atmosphere the observer notes the variable irregularities of illumination which must belong to the atmosphere because they do vary. He will see several kinds of variation in the illumination. The first, and one which is most familiar to us, is twinkling. This is most conspicuous with a very small lens—with the naked eye, for example—but on trial it has been seen nearly always in field glasses, very frequently in a three-inch lens, often in a six-inch and once or twice in an 18-inch glass. It was once suspected in the 24-inch.

Different Kinds of Currents.

In a large telescope there is one form which is called the "ordinary" current, which is almost invariably seen. It consists, as described, in light and dark lines passing the lens longitudinally, varying in density, in rapidity of motion and in distance apart. Frequently—in some localities nearly always—there are two ordinary currents moving across the field, quite similar in appearance or, more rarely, quite unlike. Often also, when one current is conspicuous a branch will begin to form, first having a direction nearly parallel to the main current and then gradually turning until it attains an angle of as much as 45°, when it suddenly ceases.

The form which is called "mottled" impresses one as something different but I am inclined to think that it is the ordinary current with a less rapid motion, for the reason that I have seen an ordinary current decrease in speed and become mottled. The fact which most strongly suggests its being a different kind, or at least having some special cause, is that it often causes the seeing to grow much worse. It is, however, always slow of movement and has the appearance of light and dark globules scattered over the lens. A similar appearance may be produced by pointing the telescope on a star at low altitude with or against the direction of motion of the most conspicuous current, thus reducing its apparent motion—a fact which verifies the idea that it is a slow form of the ordinary current.

There is another form, not at all common, which has certain similarity to the mottled but which arises from a different cause. It may be called "vibration" or "vibrating effect" and consists of light and dark globules upon the field that appear to pulsate without any marked change in position. I think however from carefully watching them that this form is the result of two nearly

equal currents of the ordinary form crossing rapidly at about right angles. When this is visible in a large instrument the lens of a small telescope appears to twinkle; and this is certainly one cause of twinkling to the naked eye—the crossing of the currents. The mottled form when moving very slowly could, I believe, produce the twinkling but the ordinary form moves too rapidly to allow the naked eye to perceive the variations of light it receives. Twinkling then, usually means that there are two currents passing overhead in different directions, whose waves are farther apart than the diameter of the lens in use.

One form remains to be described; it is the "floating" or "syrup" form. It resembles in appearance the curved streaks produced by stirring syrup and water together and is very variable in its motion seeming to float in the air above the objective. It is the most persistant of any of the forms, having been absent only once or twice out of some hundreds of observations. In order to see this current distinctly it is sometimes necessary to decidedly change the focus of the eye which fact suggests a very strong refractive power in the current. The waves are almost universally close together, long and irregular in form and have a tendency to suddenly start off with a rush in any chance direction.

The mottled and floating forms are the only ones which show their actual outlines in the air. It is probable that the shape of the waves in the ordinary form of current is similar to that of the mottled form; it is certain that it is not merely a longitudinal wave, because the variation it produces in the position of a planet is almost always equal in all directions. Both mottled and floating wave-shadows cast by electric lights on the sides of houses are often quite evident.

Methods of Seeing the Waves.

The first and most direct mode of observing the atmospheric currents is by placing the eye in the focus of the objective. The currents cast, as it were, their shadows on the objective and as all the light is concentrated in the focus, the eye can, without changing position see all the irregularities in illumination which take place over that area, that is, in the cylinder which extends from the lens to the limits of our atmosphere in the direction of the star. In the case of a planet of sensible diameter this volume is a truncated cone with its smaller end at the objective, instead of a cylinder. These differences of illumination are not real shadows but are condensations or rarefactions of light

caused by the refractive power of the air. When, therefore, the objective brings all the light to a focus, the light from certain portions of the waves comes together inside the principal focus, and from other portions outside, so that an eyepiece may be placed behind these foci at proper distances and the waves seen through it. This operation will be referred to below.

The currents of course are usually observed at night but they may be seen in the daytime by using a small diaphragm at the focus to exclude the greater part of the light of the sky. By day they are extremely handsome and are characterized by an excess of the syrup form.

A difference is produced by the object at which one looks. The ideal object is a star in which the contrast in the waves reaches a maximum; in fact at times the little irregularities become so conspicuous that it is difficult to distinguish the more important main currents. A planet with a diameter of less than 30″ shows nearly everything in a fashion convenient for observation but a large planet like Jupiter has often failed to show certain fine currents at all, or with difficulty, and has made coarse ones appear fine. This depends on the height of the current and is due directly to Jupiter's great diameter, as will be explained below.

Features of Atmospheric Currents.

Direction.—The apparent direction in the telescope has to be reduced to the horizontal direction so as to name the point of the compass from which the stream is coming. It is usually sufficiently accurate to hold a pencil so that it may be seen by the eye not at the focus, placing the pencil in the general direction of the current and then considering where it would intersect the horizon if extended.

Size.—This is also observed with the eye in the focus, and may be found by dividing the diameter of the objective by the number of parallel streaks which appear to cross it. This is a rough method but it gives all the accuracy required and is easily done. Such estimates should be made on a star or small planet and if at low altitude a rough correction should be made to find the size of the waves if they had been in the zenith.

Rate.—The motion of a current passing such a small field is very difficult to estimate except in the roughest way; the words "swift" or "slow" are usually sufficient to indicate what is seen. I have attempted to make a more careful measure of the rate but have been very uncertain about it as I had nothing with which to verify my results. Slow currents should always be mentioned.

Conspicuousness.—This is one of the most important notes to make as the seeing is directly dependent upon it. I have as yet been unable to form any direct standard of conspicuousness and it therefore becomes purely a matter of experience. It should always be remembered that the diameter of the object viewed makes a difference in the relative conspicuousness of different currents.

Constancy.—This refers either to continuousness of existence or steadiness of direction; usually the two go together, a current inclined to shift its direction being rarely permanent. This, however, does not apply to the floating form which is always changing direction and yet is practically permanent.

Height.—This is a difficult feature to observe because a scale has to be put on the sliding tube and the eyepiece run out until the particular current comes in focus. Owing to the extremely small portion of the lens which receives the graduations of light from a particular wave the focus is usually very indefinite—one has simply to do the best he can. The distances actually obtained are those of the points of convergence of light both above and below the waves, produced by the refraction in their slopes. Upon moving the eyepiece outside the principal focus the first focus reached is that of the highest system of convergent points which has anything like good definition; the next focus corresponds to the next lower set, and so on. If the refraction is such that one set of points would occur below the level of the telescope its distance behind the lens may be found by moving the eyepiece inside the principal focus (just as distances above the lens are found by the extension of focus). It is probable that only one set above and one set below the waves are sufficiently definite to produce foci. If the altitude of each of these sets is obtained, the altitude of the wave system must be half-way between them. I have attempted to verify this conclusion by actually comparing the distance apart of these two "principal" convergent planes as obtained by the change in focus and as obtained by the separation of the waves and their refractive power deduced from the vibration of the image in the focus.

The tabulated results are as follows:

Date 1895.	Altitude Wave-System.	Waves to convergent planes. By Focus.	By Vibration.
	feet.	feet.	feet.
Jan. 9	10,000	6,600	2,900
Feb. 19	14,000	11,800	10,500
Mar. 17	9,000	4,800	5,600
And on artificial waves,			
Apr. 24	290	18	83

The observations of April 24 were made upon artificially produced waves at a distance of 300 feet, through a 6-inch telescope pointed upon an artificial star at a distance of 450 feet. The correctness of the distance obtained by change of focus, exhibiting an error of only three per cent, is quite satisfactory and that indicates, as I had previously decided, that the chief trouble in this method of obtaining wave-heights is not in the focus but in estimating the amount of vibration due to a particular wave-system. This explains, I have no doubt, the disagreement in the last two columns, in two out of four cases above and yet this estimation is of importance because often we have to depend for the altitude of the wave-system solely on the altitude of one convergent plane and the estimated vibration and size of waves. In making such observations I believe it is best to observe the lower limit of the upper convergent plane and the upper limit of the lower plane, when possible, and the maximum vibration that can be attributed to the system. The observed distance from wave to wave has to be divided by two to give the separation of adjacent slopes.

A correction must be made for the apparent altitude of the star in use, since the quantity obtained is a function of the distance of the waves from the objective. If the waves give good contrast and definition, this method is capable of considerable accuracy and might be applied to obtaining the height of well-defined and brilliant clouds. I have tried it on a terrestrial object which had a measured distance of 8.6 miles, with an 18-inch objective, and obtained the result of 8.5 miles. It is well to note also whether a current seen without the eyepiece, shows more distinctly by throwing the eye out of focus.

Seeing.—Of course a record is always kept of the seeing but in this connection more precision is desirable. It is not enough to judge merely from experience, especially since we have the good and definite scale of seeing devised by Professor W. H. Pickering which has already been published once in connection with this subject and which I give below in a slightly modified form, derived from, and therefore adapted to, a 6-inch telescope.

With sufficient power (100 to 150 to the inch) the star image consists of a large central disk and a series of rings.

Seeing 12. Disk well defined, rings motionless, image motionless in field. Perfect seeing.
Seeing 10. Disk well defined, rings motionless, image moving in field.
Seeing 8. Disk well defined, rings complete but moving.
Seeing 6. Disk well defined, rings broken into dots and lines but still traceable.
Seeing 4. Disk well defined, no evidence of rings.

Seeing 2. Disk and rings in one confused mass, constant motion, no increase in size.

Seeing 0. Disk and rings in one confused mass, violent motion, image greatly enlarged (for example to twice the diameter of outer ring).

This scale of seeing changes with the size of the objective, but it may be made complete by noting, in addition to the appearance of the stellar image, the character of its motion. In fact the ideal scale of seeing is one that depends solely on the motion of a stellar image such as would be obtained by a telescope of extremely long focus and very minute aperture. Perhaps some day when photographic plates are more sensitive, this observation will be made by photography; to-day it can be done by turning on a bright star, like Sirius, putting a very small diaphragm over the objective and setting the two micrometer threads at one or two seconds of arc apart and watching the motions. Practically Professor Pickering's scale with a few notes on the motions of the planet or star is at present a less difficult form to give the observation.

Having directly compared a 24-inch with a 6-inch in the use of this scale, I find the 24-inch wholly unequal to exhibiting many gradations of seeing which are of common occurrence. As nearly all observatories have a 6-inch telescope, or one of about that size, or can diaphragm a larger instrument, I recommend the universal adoption of the above scale and aperture as the standard. By the present addition of seeing, 12 and the motion of the image in the field, the scale is made to cover those changes in seeing which are only of consequence in the use of enormous apertures under remarkably favorable atmospheric conditions.

Similar Phenomena.

In order to understand the subject better let me cite a few familiar cases of the same or similiar phenomena. The most ordinary instance is met with in sunlight upon shallow water. There, beneath each rising wave, the light is condensed, while beneath each trough the light is enfeebled. At a certain depth depending on the character of the waves the contrast between the crest and the trough is most marked. Upon going deeper the difference decreases leaving finally only light and dark patches. I conceive the waves in the air to be very similiar in their action though having a different origin and with an extremely slight refractive power.

Other very familiar examples are to be seen in the wavy motion of objects seen across a desert, across the top of a hot stove, or over a camp fire. I have often seen atmospheric waves upon the

sunlit sill of an open window when the difference between the inside and outside temperatures was very great. They show at night on the sides of white houses which are not too far from a brilliant electric light.

A less well-known case is that of shadow bands or wave-shadows at the beginning and ending of a total eclipse of the sun. The reason that shadow bands are not always visible in sunlight is perfectly simple and exactly the same as for the fact already mentioned that certain atmospheric currents do not become visible when viewing Jupiter. Each point on a light-giving disk casts its own set of shadow waves. When different points can be far enough apart for their respective shadows to overlap each other, an even illuminated surface results. That is what happens ordinarily with the Sun and Moon, and even with Jupiter. At the moment of a total eclipse however when the visible part of the Sun is greatly reduced they show, presenting undoubtedly an erroneous wave-form because the source of illumination is a line or thin crescent instead of a point or small circle. In the shadow bands of April 16, 1893, they were in the form of slightly curved wave-crests moving in a direction perpendicular to their length. This direction of motion would imply great similarity to waves on water but we were left in some doubt as to the cause of this coincidence because their length was also roughly in the same plane with the visible crescent of the Sun. They were observed at an altitude of nearly 4000 feet above the sea. At sea-level they were at the same eclipse observed to be longer and perhaps less well-defined.

The absence of shadow bands of great size suggests that a large telescope can usually present to view all existing currents.

Causes of the Current Phenomena.

The causes to which these phenomena are assigned have already been suggested but not as yet distinctly discussed by themselves.

These so-called waves are lines of irregular refraction in the air due to non-uniform density. The irregularities in density are due, I am convinced, to irregularities of temperature. The ease with which change of temperature may cause them in comparison to change of pressure may be observed in the following way. Wave a large, strong fan violently backward and forward in front of the lens when the telescope is pointed on a bright star; with great care the lines of pressure may be seen, resembling the curved wave that follows the tip of an oar in the water. Then

try the bare hand in front of the objective, and the lines showing the movement of warm air from the surface of the skin are at once apparent:

The general cause of change in temperature so far as I have traced them are given below.

Convectional currents.—These seem to produce chiefly, and perhaps only, the syrup form.

Settling of cold air at night.—This settling occurs in valleys or level plains when there is not too much wind. I do not know its effect in an absolutely quiet air but in valleys where it can have a downward motion it is productive of extremely bad seeing, with very conspicuous and rather small waves.

Mountains or Hills.—The experience at Flagstaff, already cited, indicates that when standing well up above the horizon they have a bad effect on winds passing over them.

Snow.—A Flagstaff experience similarly indicates that snow is extremely deteriorating. In each of these cases the size of the waves was merely a good average—neither large nor small.

Cloud Condensations.—This theoretically should cause changes in temperature, and clouds, especially moist clouds, actually cause changes in the appearance of the currents, making them coarser for the time being. It is difficult to say what is the cause of the coarse or fine currents but it is possible that it depends on the humidity of the air.

Streams of Air at Different Temperatures.—This does undoubtedly produce local changes of temperature, sufficient to cause bad seeing but is obviously a difficult matter to study. In a very local way it may be investigated by a thermometer. I have been able to detect a rise of 2 F. at some distance to the leeward of a house; which shows how very bad a large city must be and the necessity of placing large instruments at considerable distance from them. In fact the population of a region is a factor worth considering in locating an Observatory.

Remarks upon the Floating Form.

There is a very marked difference in this form between day and night. By day it is extremely conspicuous and full of movement, at night it is often difficult to distinguish. It always moves about in the way that smoke does in a draughty room; it is very similar in appearance to the intense heat lines produced by a lighted lantern in front of the objective, or to the lines about the hand under similar conditions; it requires a great extension of the focus to bring it into view with the eyepiece. From these

facts I conclude that it takes its origin in the layer of comparatively calm air that exists between the surface of the Earth and the lower great stream overhead. It is in this layer that the main convectional movements occur by day. That I think is the reason of its greater conspicuousness and activity during that time. With a large planet like Jupiter it perhaps shows less change than the other forms, indicating thereby a low elevation.

It does not seem to exist in the telescope tube because it shows no association with the outline of the lens nor have I ever seen the entire lens vibrate, which would sometimes happen if there were currents of any consequence within the tube. Elaborate means have sometimes been taken to prevent movement of air within the tube but after trying to see real evidences of such movement and failing I am forced to conclude that none exist.

It is more difficult to say whether any of this current comes from the dome but so far as I have observed I am inclined to think not. For the comfort of astronomers in cold weather it would be well worth trying to heat the dome, preventing the exit of any hot air near the tube by a rubber-cloth curtain which would hang down inside the shutter entirely filling it, and be tied around the end of the telescope. By watching the currents of this character one could easily tell if the heating did any damage at all to the seeing.

The floating form is the one most commonly seen without telescopic aid or in very small glasses such as surveyor's transits. Over dry ground, especially in tropical countries, its effect may usually be seen at midday with the naked eye. Owing to the source of light being an area instead of a point, no variation of illumination is produced, but the object becomes disturbed and distorted through the refractive power of the air waves. As one minute of arc is roughly the smallest angle visible to the naked eye under ordinary conditions of illumination we may easily put the refraction of these waves at 5′ to 20′. Of course it must be constantly exceeding even these figures when the conditions are particularly favorable.

Effects of Currents on Seeing.

The immediate dependance of the seeing upon the atmospheric currents is a continuous experience. With an increase in the number of the currents the seeing at once grows worse, and the direction of the current may have a large effect, some being habitually bad and others always good. The cause of such difference is to be sought for in local topography or in general climatic condi-

tions. The conspicuousness of a current is its most directly influential feature as it is a direct result of the refractive power of the waves and upon this depends the vibration of the object in view and its consequent distinctness of outline and detail.

The refractive powers of the various telescopic forms of waves, are as follows: The ordinary form rarely exceeds 1″ or 2″, while its usual amount is much less, say 0″.3. The mottled form has an average of about 1″ and goes up to 8″. The floating form has usually a low refractive power at night but when very bad may reach up to 10″. The ordinary form which is caused by the settling of cold air at night sometimes considerably exceeds this even reaching 25″, and that due to snow not infrequently comes near it. These figures are derived from observations on the motion of Mars in the focus and are given from a brief examination of a large number of observations. There is so much variation in the recorded amount of vibration that these figures can only be regarded as general approximations.

The average characteristics of waves of the ordinary form observed in Arizona and Mexico (each at an elevation of about 7000 feet above sea level) were as follows: direction, westerly; size, 1½ inches, and rate, roughly 10 miles per hour. The average size of the floating form was about ½ inch.

The Telescope; Its Apertures.

Bearing in mind the foregoing facts in regard to the constant presence of air waves which are only a few inches apart and have a measurable refractive power it is no difficult matter to deduce the conditions under which certain apertures become preferable.

It is easily a matter of observation that, making allowance for the variation in brilliancy of the apparent field when the eye is in the focus, the atmospheric currents are precisely the same in telescopes of different apertures at the same time and place. This is of course what should be expected. But different apertures do change the character of the seeing; and this also is what we expect. Conceiving the waves to consist of crests and valleys as the waves on water, we see that the refraction takes place on the slopes between these and that two adjacent slopes refract in opposite directions. If we take the distance from crest to crest as d and the mean amount of refraction in each slope as r seconds we shall find that in a telescope with an aperture of $\frac{1}{2}\ d$ or less the image in the focus will oscillate through a distance of $2\ r$. If the aperture of the telescope is d we would see in succession, if the waves were all of perfect form, first a haziness of the planet,

then a displacement of r seconds in one direction, then a haziness followed by a displacement of r seconds an the other side of its original position, then a haziness as at first, and so on; the haziness in each case being due to the presence of two slopes at once before the lens. If the aperature were $1\frac{1}{2}$ d there would be alternations of haziness with these displacements of r seconds, the displacements themselves being not entirely free from haziness. With further increase of the size of the objective displacements would for a time exist but become more and more hazy until at last they would cease, leaving the planet perfectly steady but blurred.

Such is the effect of using different aperatures. As a matter of fact we rarely have such simple conditions in actual experience. We have a given telescope and usually three series of air waves which may be all of different sizes. By a big diaphragm we can get rid of the blurring effect of the largest set. By medium and small diaphragms we can improve successively the bad effect of the other series but in doing so the light is enormously decreased. We may summarize this matter of aperture by saying that the smaller the aperture the more bodily motion and less confusion of detail; the larger the aperture, the less bodily motion and the more confusion of detail. This leads us directly to the aperture required for certain classes of work. For seeing planetary detail we should use a small aperture unless the seeing is at its very best. On the other hand for micrometer work when steadiness of the image is required we need a large aperture. On one occasion after taking a large number of diameters of Mars and assigning weight to each measure, I found that the agreement of the readings was almost inversely proportional to the assigned weights. I then remembered that I had judged the weights according to the distinctness of the limb and detail. Upon changing my criterion to the steadiness of the image in the field, the weights then become of real use in judging the relative value of different measures. Of course there is a limit to which this increase of aperture may be carried for the planet may become so ill-defined that micrometer measures are worthless. One has to tell from experience when this limit is reached.

Good seeing then, apart from transparency of the air, consists of two factors, steadiness and definition. In a given atmosphere these factors vary with the aperture, one being improved at the expense of the other; either one may come from a superior atmosphere. Let no one therefore be deceived in attributing to his atmosphere what is really due to the relation between the diame-

ter of his telescope and his class of work. For an accurate record of the quality of the seeing I earnestly recommend observers to use the scale already given.

Eye-End Diaphragms.

It is usually rather inconvenient to put on and take off diaphragms, so it is worth remembering that to a large extent the same effect may be produced by using small diaphragms over the eyepiece which cut down the pencil of light entering the eye and so reduce the affective area of the objective. For a given diaphragm the amount of reduction varies with the focal length of the eyepiece. These eyepiece diaphragms have been tried by the writer to great advantage.

This idea of placing obstructions between the eyepiece and the eye has a further use. The field of light about a very bright star is largely due to chromatic aberration, the impossibility of bringing all colors to the same focus. Through the refractive effect of the atmospheric currents and sometimes through the projection of opaque objects into the circle of the lens (for example, tin-foil separating the glasses) this field, consisting of many concentric rings, is divided off into series of rays. In searching for faint companions to bright stars these rays are extremely objectionable and anything which will help to get rid of them will be of value.

The objectionable field light produced by any given point in the objective lies almost entirely across the focal image in a line parallel to one joining that point and the centre of the lens. Therefore by placing across the objective or behind the eyepiece bars of suitable size all the field light may be cut off in a line parallel to that bar without making any very great loss of light. Experiments may be made in this line by merely thrusting a knife-point in front of the eyepiece.

The Observer; Optical Qualities of the Eye.

Aperture has another effect on the seeing which is of different kind, namely, physiological. It principally concerns observers of planetary detail and doubtless has frequently been explained by them.

All the effects of this kind observed, vary with the size and brilliancy of the pencil of light entering the eye. The first imperfections noticed are motes which float about and persist in coming upon the planet which is under examination. They can also be seen against a clear blue sky. They often have the appear-

ance of minute twisted hairs and sometimes show signs of a cell-like structure—a fact which is more than suggestive because they undoubtedly are the remnents of cells floating in the liquids which fill the parts of the eye-ball. When they come upon the planet they may be disloged by a quick motion of the eye to one side, but that is only for the moment as it seems to stir up a commotion and others quickly follow. With these as with other imperfections to be mentioned, their maximum conspicuousness belongs to a certain intensity of light. With very bright sources of illumination they do not interfere; yet their range is very great and I know of no possible way of getting rid of them. To the naked eye they are perhaps a little less likely to appear under faint lights because the pupil is enlarged and they must be very close to the retina to throw any distinct shadow. In telescopic work their probability of appearing is inversely proportional to the square of the diameter of the pencil of light which enters the eye and they are therefore less likely to appear with low powers. High powers have the further disadvantage that they greatly reduce the apparent light of the planet and often render the motes more conspicuous in comparison. From their apparent size when projected on Mars I infer that their real size within the eye is between one and two one-thousandths of an inch.

Another region in which imperfections occur is the outer surface of the eye. These become visible when the pencil of light entering the eye is extremely minute and of the proper brilliancy, by the casting of their own shadows, as it were, on the retina and the absence of enough light from other parts of the pupil to drown them. With extremely high powers they begin to appear and it need hardly be added that high powers show more of the imperfections of the eyepieces for a similar reason. These imperfections in the eye are extremely small and consist usually in streaks or drops of moisture, bits of dust and lines of compression, probably on the cornea.

Lack of correctness in the curves of the refracting surfaces of the eye is another source of trouble. Such general imperfections as myopia or astigmatism can be fairly well corrected by glasses but there may easily exist in many eyes somewhat more local irregularities of curve which glasses cannot help and which therefore spoil the definition of the eye. It is a well known fact that some observers prefer high powers and some low. It seems possible that one cause of an instinctive preference for a high power may be certain local imperfections in the surfaces of the eye because, if fairly large, these imperfections interfere less with

the small pencil of light emerging from high-power eyepieces than with the larger pencils from low-power eyepieces. For persons with eyes defective in this way there is a real advantage in using high powers.

But perhaps the most harmful imperfection in the eye is the lack of homogeneity within the more dense transmitting media, either the lens or membranes, probably the former. Under proper conditions the lens (presumably) displays irregular circles and radial lines, the whole resembling a spider-web structure. Under actual tests this structure is so very prominent that we wonder how the eye is able to give such good definition as it does. No optician could ever sell a lens so badly made except for the coarsest usage; in proportion to its size it has the imperfections one finds in the lens of a bull's eye lantern.

A most simple and instructive method of examining ones own eye is by taking two double concave lenses from a pair of opera glasses and looking through them at a candle some ten feet distant; by holding one lens near the eye and moving the other backwards and forwards the illumination may be adjusted to produce the best contrasts. In the experiment the pupil is seen as a circle of light and, if the candle is bright enough, concentric interference rings may be seen at its edges. After a few trials the motes in the eye, the irregularities in density in the lens or membranes and the drops and streaks of moisture left by the eye-lid may all be seen. It is probable that irregularities of the refracting curves such as spherical aberration and astigmatism can also be made evident by this device. In spherical aberration the center should appear brighter or fainter than the edges, while in astigmatism there should be a bright or dark band across the center from side to side in a direction depending directly on the line of astigmatism. It is possible, however, that spherical aberration could be produced merely by throwing the light into the eye in this unaccustomed manner just as it may be produced in a telescope by reversing the lens. Minute local errors may be seen as light or dark spots and the semi-permanent effects of holding the lid closed by force for a moment, impresses one with the fact that such usage of the eye is very bad for its power of definition.

One might guess at the errors of curve quantatively but if sufficiently large they can be actually measured by using a telescope, micrometer and artificial star. Let the micrometer be illuminated from one side and put a very small stop on the telescope so that the emergent pencil shall be very small. Under these conditions the entire pupil will receive the light from the threads but only a

very small part of it will receive the light of the star. By passing the pencil of light through different parts of the pupil the error of any one point with regard to the whole may be obtained. It is possible that this usage of the telescope combined with a slight spherical aberration in the eye, is sometimes a cause of the "parallax" attributed to eyepieces. By carrying this process to an extreme one might even measure the refraction in those minute permanent marks in the eye which become evident upon careful examination. These marks are about one one-hundredth of an inch apart, so that a pencil of light as small as one two-hundredth of an inch would be required for measuring them.

Contrast.

This is a subject but little understood although it is of great importance in research upon planetary markings. The elementary fact is that high powers greatly reduce contrast; when one changes from a low to a high power the light parts of the planet become correspondingly fainter but the dark parts seem to become lighter; a perfectly black marking, however, such as the shadow upon Jupiter of one of its satellites, remains practically unchanged in good seeing. In an experiment for testing the effect of illumination on contrast, eyepieces were placed in the 24-inch telescope and its 6-inch finder so that a magnification of about 200 diameters was produced in each. Jupiter was examined and although work in the 6-inch would have proved more difficult owing to the greater conspicuousness of imperfections of the eye no especial difference in contrast for the larger markings could be perceived. The same result was obtained upon trying a power of 750 in each instrument. It was therefore concluded that illumination and probably the size of the spurious disk and the size of the emergent pencil have practically no effect on contrast within a large range but that magnification has. Illumination however, does effect color contrast, for the greater the illumination, the more brilliant and conspicuous are the colors.

No doubt the chromatic aberration of a lens (its scattering of light in a large field about the focus) has much to do with contrast; for the scattered light from each point on a planetary disk helps to reduce the contrast on all other parts of the disk within a certain distance. If we consider for a moment the image in the focus it is apparent that this destruction of contrast will be the same in two lenses of the similar curves and equal ratio between the aperture and focus, no matter what the actual aperture be; but it is also evident that diaphragming a given lens will reduce

scattering and tend to aid contrast, or, to express it differently, long focus lenses should be beneficial to contrast. We conclude, then, that, as well as improving the seeing, diaphragming may improve the contrast provided the disk is not decreased too much in brilliancy, and that diaphragming a large telescope is better than using a smaller instrument of shorter focus.

Seeing of course has an effect on contrast because the refraction in the air waves causes a spreading about of the light from the object in view. Dust on the lenses causes loss of contrast for a similar reason. But under given conditions of seeing the marked effect of a change in power cannot be due to seeing because there is no relative change in the size of the object under examination, the atmospheric waves and the lens.

Apparent contrast, then, is a function of the size of the impression on the retina. The only explanation that suggests itself is this: The part of the retina most sensitive to slight contrast is the "yellow spot" which is also most sensitive to definition. It is quite likely that after a faint marking becomes large enough to be seen at all it will show maximum contrast when its retinal image holds a certain relation in size to the yellow spot. For markings of different densities it is possible that this dimensional relation changes.

The eye has considerable power of adapting itself to contrast occurring in different intensities of light in a manner entirely independent of the size of the pupil. This has often been exemplified in the experience of visitors looking at Mars, when the emergent pencil was much smaller than the pupil of the eye; at first they see nothing but a glare of light but after looking sometimes for fifteen minutes the glare diminishes and markings begin to appear. This is a certain power of adaptation which I have never seen mentioned before. After much practice that first glare becomes less and less noticeable and the eye becomes more sensitive to the particular range of contrast sought. That in fact is the training required by the eye to discern planetary detail and for different planetary bodies which present different degrees of contrast and different intensities of light, the training has to a certain extent, to be undergone afresh in each case.

It is a result of this training helped, perhaps, by some natural difference in eyes that two observers may find contrast more marked and detail easier in entirely different intensities of light. This point is best exemplified by the fact (very familiar to ourselves) that of two observers examining Mars on alternate nights one saw extensive and intricate detail in the light regions of the

planet and the other observed numerous markings in the dark parts, but that for the entire opposition neither one saw much of importance in the other's region. The sequel is interesting, for during the opposition just passing each one has made a special and continued effort to train his eye for markings in the other intensity of light and so far succeeded that each has corroborated the other's previous work. This corroboration was not due to prejudice but to perseverance.

He will greatly benefit work in planetary detail who constructs an apparatus for increasing contrast. The polariscope has been tried with success upon clouds in our own atmosphere because it darkens the background of the sky. In astronomical work we need some medium which, without spoiling the definition, will cut off all the light which comes from the delicate gray-green or blue tones of planetary markings.

OBSERVER.

The observer has already been mentioned as ranking very high in order of importance. It is not merely that the best observers of planetary detail are able to recognize what they see and draw it but it will be noticed that they have been very diligent in working often on unpromising material and amidst discouragement from other laborers in the same field. To everyone at first view all fine planetary work seems almost impossible and that is why all those who do not pass through this first stage discredit results that are finally proven to be of the greatest value. If one would see something he must persistently and persistently keep at it, picking up bits of detail, little by little, even though the seeing seems bad and the object difficult, always and only with the stern determination to see something if that something exists. The final pleasure of seeing his disjointed observations take shape in one consistent whole, is his reward.

LOWELL OBSERVATORY, Mexico, April 2d, 1897.

THE STUDY OF THE VARIABLE STARS. V.

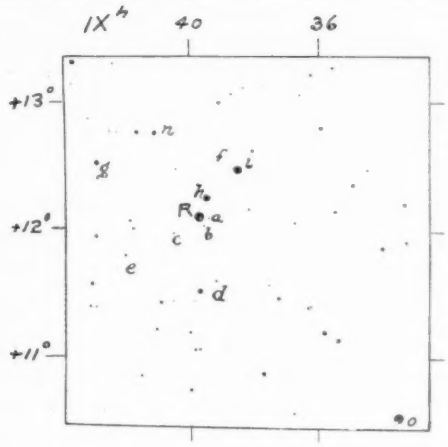
PAUL S. YENDELL.

FOR POPULAR ASTRONOMY.

3493 R LEONIS.

α	8^h	39^m	45^s	$\delta + 12°$	5.9 (1855)
		42	11	11	53.6 (1900)

Among the older variables of the long period type, perhaps, after Mira, there is none which is at present of more interest than R Leonis.



REGION OF R LEONIS.

Its variability has been known for more than a century, having been discovered by Koch in 1782.

As in the case of *o* Ceti, the following sketch of the star's history is drawn from that of Argelander, in the seventh volume of the Bonn Observations.

Koch announced the variability of this star in the *Berliner Jahrbuch* for 1788, and in the same place gave also the first rough observations. In the same publication for 1793 and 1797 he gave but little better information, and only in the number for 1803, p. 226, do we find the announcement of an observed maximum. At the same time Koch gives an estimate of the period, so nearly correct that we are led to conclude that continuous observations must have been made, of which, however, no trace is anywhere to be found. The star was almost entirely neglected, especially in the early decades after its discovery, and Pigott alone looked for it occasionally, but as he says in *Philosophical Transactions*, 1786, p. 194, always in vain.

A search among the older star-lists yields the following crumbs of information:

Flamsteed did not observe the star, but only its two neighbors 18 and 19 Leonis, both on 1691, March 19 and 20, and 1705, Nov. 19: and on 1691, Nov. 12, only 19 Leonis, which is but 8½′ distant from the variable, and much fainter than the latter when at maximum. R cannot have been near its maximum on any of these dates, since Flamsteed would in that case certainly have observed it. Observations of the brighter star 18 Leonis, which, though half a degree distant, must yet have been in the same field of the quadrant with the variable, are found on 1695, Dec. 23, 1701, Mar. 21, 1713, Feb. 16, 1715, Feb. 16 and 19, all *O. S.* So that on all these dates R would have been observed had it been bright, for at its maximum it is always brighter than 18 Leonis to a greater or less degree, sometimes nearly a magnitude.

Bradley observed our star on 1753, Nov. 5, 1757, Mar, 20 and 25, inasmuch as he mistook it for 19 Leonis; so that it must, at these dates, have been considerably brighter than the latter, and near its maximum. On the other hand, it was probably fainter than its neighbor on 1755, Mar. 1, 30, April 4, Nov. 25; 1756, April 10 and Nov. 25, on which dates 19 Leonis itself was observed, and no mention is made of the variable.

Mayer's single observation is on 1757, Mar. 30, and the magnitude estimated as 6th, while that of 21 Leonis is given as 7th.

D'Agelet did not observe the variable, but 18 and 19 Leonis 1783, April 8 and 14, and Feb. 26. He, however, was observing Flamsteed's stars mostly, so that this decides nothing.

In Lalande there is one observation, 1796, March 16, 9^m. On the same date he estimated the stars D. M. + 11°2088, 2094 and 2117, which in that catalogue are respectively $8^m.9$, $8^m.7$ and $8^m.7$, as of equal brightness with R; so that we can assume that the variable had at that time the D. M. magnitude $8^m.8$: R arrives at this brightness on the average sixty-three days before and eighty days after the maximum.

Piazzi observed R from 1801, Feb. 21 to Mar. 6 as $7^m.8$, and Mar. 10-15 of the same year as 8^m. In the first series he assumed the magnitudes of P. IX^h 163 and 23 Leonis both as $7^m.8$; in the other, that of 19 Leonis as 7^m and of P. IX^h 165 and 184 as 8^m. The two first named stars have the magnitudes respectively of $7^m.0$ and $6^m.5$ in the Durchmusterung, so that R would at that time have been approximately at the $6^m.8$ by the D. M. scale. The three stars of the other series have in the Durchmusterung the magnitudes respectively of $7^m.0$, $7^m.5$, $7^m.8$, so that the magnitudes found from for the variable is $7^m.8$. If we assume that these estimates are correct for the mean dates, the maximum would fall by the two series respectively on 1801, Jan. 8 and Jan. 4.

Westphal's observations are to be found in the *Zeitschrift für Astronomie*, Vol. VI, p. 283. He deduces a maximum from them on 1818, Feb. 11, but Argelander considers Feb. 14 to be a better approximation, as found by a mean curve, deduced from his own observations.

Baxendell observed our star with great persistency and has published the maximum indicated by his observations in the *Monthly Notices*, Vol. 17, p. 235. If this careful and thorough observer had given his individual observations in detail, they would have been of great value. It is much to be feared, however, that these valuable observations have been lost, like so

many others by the earlier observers in this interesting branch of astronomy. (Argelander himself has set a fine example by publishing all his own observations of variables, which occupy the last 115 pages of Vol. VII of the Bonn Observations). Baxendell's maxima up to 1884 may be found in the *Observatory*, Vol. VII, p. 169.

Later observations by various observers may be found in the *Astronomische Nachrichten* and the *Astronomical Journal, passim.*

Argelander assembles a list of thirty-two maxima from 1757 to 1866. The first six, deduced from the observations quoted above, are too uncertain to be assigned weight in the deduction of the elements of the star's variation, and reliable data begin with Baxendell's maxima, in 1840. Argelander finds a diminishing period from $312^d.73$ in 1810 to 312.19 in 1855. These are from means of long series, and the effect of the periodical irregularity is masked in them.

Since the date of Argelander's discussion the star has been well observed, and I have succeeded in accumulating a series of fifty-nine maxima, down to Epoch 163 observed in November, 1896. This list, though not exhaustive, is quite sufficiently continuous for useful examination of the elements.

Schönfeld, in his Second Catalogue (1874), gives the period deduced from the observations since 1818 as $312^d.6$. Chandler in his First Catalogue gives the elements of maximum, 1880, April $28.4 + 312^d.87$, with the remark that there is good evidence of periodical inequality. In the Second Catalogue he gives a value for this inequality, the elements there given being 1757, April 21 $+ 312.90E + 25^d \sin (2°.75E + 318°)$. In his Third Catalogue, for reasons which will be adverted to below, he does not give a value for the inequality, but simply the mean period, the last elements of maximum being 1757, April $26 + 312^d.8$ based upon fifty maxima and sixteen minima.

Up to 1890 the elements of Chandler's Second Catalogue represented the observations fairly well; but the maximum of E 155, in 1890, shows a sudden change of sign in the residual, which has been persistent in all the observations since that time, the departure from the computed date amounting in 1895, E 162, to — 38 days, by three very accordant observations of maximum, by as many different observers, and in 1896, E 163 to — 43 days.

The following table gives these residuals:

	d		
E 128	− 5.0	observed by	Schmidt.
148	+ 5.7	" "	Baxendell.
149	+ 2.7	" "	"
"	+ 6.7	" "	Sawyer.
153	+ 6.3:	" "	Yendell.
154	+ 11.3	" "	"
155	− 7.3	" "	"
"	+ 4.3	" "	Gore.
159	− 21.4	" "	Gruss & Láska.
160	− 22.4	" "	H. M. Parkhurst.
"	− 25.4	" "	Corder.
"	− 28.4	" "	Sawyer.
"	− 23.4	" "	Pereira.
161	− 39.2	" "	Yendell.
"	− 28.2	" "	Corder.
"	− 41.2	" "	Sawyer.
"	− 15.2	" "	Pereira.
"	− 50.8	" "	H. M. Parkhurst.
162	− 39.0	" "	Flanery.
"	− 38.0	" "	H. M. Parkhurst.
"	− 38.0	" "	Yendell.
163	− 42.7	" "	Flanery.

To attribute this departure from computed dates to an actual change in the law of the star's variation is obviously faulty reasoning, since by so doing we assume that our previous knowledge of that law was absolute, which is very far from being the case. It is very evident that this law is far more intricate than had been supposed, and that many more years of patient observation will be necessary before we can make the attempt to arrive at it with any considerable prospect of success.

My comparison-stars and magnitudes are as follows. All the stars are shown on the chart, excepting *l* and *k* which are outside its limits, but can be found on any good naked-eye map. The magnitudes as far down as *g*, are from the Potsdam measures, and are continued below these by a comparison with the D. M. magnitudes.

COMPARISON STARS.

		Light.	Mag.
l =	ξ Leonis		5.18
k =	ν "	45.8	5.65
i =	18 "	36.2	5.90
h =	19 "	31.2	6.68
g =	21 "	27.2	7.15
e =	D. M. + 11°2108	21.2	7.83
d =	11 2102	18.6	8.15
n =	12 2099	18.6	8.15
f =	12 2091	17.1	8.34
a =	12 2093	11.6	9.05
b =	12 2094	7.5	9.55
c =	11 2105	5.0	9.88

The value of a step is $0^m.12$.

The interval between *i* and *k* is very uncertain, as it depends on only three observations, and it is probably too great. For *l* I

have no step value, it having been used only once or twice, in single-star comparisons; it is, however, one of Argelander's stars and is useful at bright maxima.

The foregoing chart, which is a copy from the Durchmusterung, shows all the comparison-stars, except *l* and *k*, as mentioned above. It will be seen that R is the following star in the little triangle of faint stars just preceding 19 Leonis, and is readily found by its configuration with that star. When near maximum it is conspicuous with the field-glass, and good determinations of this phase can be made with the help of this instrument; it is, in fact, too bright for reliable comparisons with the telescope at that stage. At minimum it is comparable with *a*, *b* and *c*, and needs at least a three-inch glass to observe it well.

Unfortunately, it will be impossible to observe another maximum of the star until 1899.

CONDITION OF VISIBILITY OF INTRA-MERCURIAL PLANETS.—CAN SUCH BODIES BE PHOTOGRAPHED?

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

The apparently most forcible argument yet adduced against the probability of the existence of any intra-mercurial planet having a diameter exceeding one hundred miles is that such a body, shining by reflected sunlight would, even when far from superior conjunction, be so bright that it would manifest itself either visually or upon photographic plates having the wonderful sensitiveness of those now employed by astronomical physicists.

It is easily demonstrable, from photometric principles, that an intra-mercurial body having a diameter of 600 miles and being at a mean distance of 0.2 would, even when at greatest elongation, shine with a brilliancy equal to that of a first magnitude star, *provided that its albedo or ability to reflect the incident sunlight, were equal to that of the asteroid Vesta* which furnishes probably the most valuable photometric standard for the measurement of planetary magnitudes, and whose diameter, as determined by Professor Barnard, is 243 miles.

In the discussion of the probability of the existence of intra-mercurial planets, the paramount question is: How much of the incident sunlight is reflected from the surface of such a celestial body, and what would be the result were there very little, or no,

reflection therefrom? It is very evident that if there were absolutely no reflection such body—unless shining by intrinsic light—would be utterly invisible in any position in its orbit, no matter what the planetary diameter may be, and it would be impossible to detect it visually, or to know of its existence, unless the body were projected against the solar disc, in "transit," or unless the planetary mass were sufficiently great to cause a sensible perturbative effect upon the motions of other known members of the solar system.

Now, it is my purpose to demonstrate that unless the diameter of any intra-mecurial planet be so great that the planetary body can be seen projected against the solar disc, when in "transit," it is almost absolutely certain that such body cannot be detected photographically during a total solar eclipse, and that its detection by visual means must, in any case, be a matter of very considerable difficulty. It is also my purpose to demonstrate that the quite positive opinion now generally held by astronomers that the peculiar celestial objects observed by Watson and Swift during the total phase of the solar eclipse which occurred on July 29, 1878 (the planetary character of which objects has always been strenuously insisted upon by those skilled observers) could not have been planets revolving around the Sun in orbits situate within that of Mercury, has been founded upon insufficient premises and that those holding the opinion aforesaid have ignored patent facts of physical science, which facts cannot be ignored if the truth in regard to this mooted question is ever to be determined, and that this question is yet far from being *res adjudicata*.

Had due consideration been given to the following enumerated and well known principles of physics, the consensus of opinion among astronomers, upon this question, would, I think, be very different from what it is.

The principles above referred to are these:

1. A good absorber of "radiance" is a bad reflector.
2. A good absorber of thermal "radiance" is a good radiator.
3. Carbon in the form of lamp black, is practically a perfect absorber, radiator and non-reflector.

Now, the reason why a planetary body of considerable dimensions can move around the Sun in an orbit situate within that of Mercury and yet be difficult of detection, either visually or photographically, during the total phase of a solar eclipse, is, I hold, due to the fact that the surface of such a planetary body is *coated with a deposit of carbon* similar to a coating of lamp

black, and that, therefore such surface is quite incapable of reflecting the "radiance" of the Sun, incident thereon.

According to the second principle aforesaid, the surface of a planetary body, so coated, is a good absorber of thermal "radiance," and consequently, much of the incident solar heat must be retained by the carbon coating which, therefore, must become quite highly heated during the time of exposure of the surface to the rays of the Sun; furthermore, according to the same enumerated principle a good absorber is also a good radiator and, therefore, it follows that when the heated surface is turned away from the Sun it must radiate and cool with great rapidity and consequently darken.

It is also demonstrable that the surface temperature of such a body must be 1,300° to 1,500°, Fahrenheit and therefore, that such surface must shine by intrinsic light of a *red* or an *orange* color, and with a full disk when the body is in superior conjunction, and that as the planet moves away from that conjunction, that portion of its surface turned away from the Sun and toward the Earth, by reason of rapid radiation and consequent cooling, must fall below the temperature of luminosity which is nearly 1,000° F. and a rapid diminution of the planetary light must take place as the body moves toward inferior conjunction. Under such conditions a planet although it be utterly incapable of reflecting the light of the Sun, and shine with an intrinsic radiance due to the temperature of its surface matter must pass through phases similar to those of planetary bodies whose luminosity is due wholly to reflected sunlight.

My hypothesis that an intra-mercurial planetary body must be coated with carbon may seem to be too strange for belief, and incapable of demonstration; but a consideration of the following simple facts leads directly to the conclusion that this condition of the surface of such planetary bodies is one that must necessarily exist. Certain well-known phenomena observed in vacuum tubes indicate, quite clearly, that there is a *radiation of matter* as well as a radiation of energy; that matter in a state of extremely fine division is transported at a high velocity (by and through the transmitting medium for "radiance") outward from any radiant surface, and to indefinitely great distances therefrom. Some years ago I set forth on the pages of the journal *Astronomy and Astro-Physics*, my theoretical explanation of this phenomenon, but it is not necessary, in this connection to consider theoretical principles—it suffices that attention be given to a phenomenon observable by any one who will take

the trouble to examine an incandescent, electric lamp under certain conditions. It is a matter of common observation that often, after such lamp has been in service for some time, the interior surface of the glass bulb of the lamp becomes coated with a tenaciously adhering deposit of carbon which can come from no source other than the carbon filament whose incandescence furnishes the light of the lamp; furthermore it is evident that since the bulb of such a lamp is generally exhausted of air to about one hundred thousandth of an "atmosphere," the deposit of carbon on the inner surface of the bulb cannot be the result of carbon vapor or smoke brought into contact with the surface by *convection-currents*, but must be due to a process of direct *radiation*—the infinitesimal particles of carbon detached from the filament being hurled, with great velocity, against the inner surface of the glass bulb, to which they adhere with great tenacity. Now the temperature of the filament when radiating 16 candle power is, according to my determination, very approximately, 2,200° F. while the surface temperature of the Sun is a little more than three times as much; whence it follows that if the temperature of the filament is sufficient to cause a radiation of matter at a rate such that the observed effects are produced, the very much greater thermal energy of the Sun must cause the radiation of finely divided matter from the solar surface at a correspondingly greater rate, and this matter must be impelled against the surface of any celestial body in the vicinity of the Sun, not shielded by an atmosphere of sufficient density, and such body must therefore be coated with the substance or substances thus radiated from the surface of the solar globe.

That one of the principle elements of the Sun's surface matter, or photosphere, is carbon in a state of fine division, and similar to lampblack, is a statement the truth of which can, I think, be made apparent by a consideration of the following facts: The spectroscope has clearly indicated that the matter of the solar photosphere whence the Sun's light emanates, is incandescent and *solid* and while the *internal* temperature of the Sun is, according to my determination, nearly 17,000° F., the surface temperature, or that of the matter of the photosphere, is 6,800° F. and the only known element that can exist in the *solid* state, even at this lower surface temperature, is *carbon*.

According to my hypothesis all the *internal* matter of the Sun being at the temperature 17,000° F. is in a gaseous—although highly compressed—state and, being so, is comparatively dark; but this matter rising in convection-currents to the surface is

cooled to the surface temperature aforesaid, the particles of the carbon vapor then becoming solid and highly incandescent and constituting the *photosphere* or the luminous shell surrounding the more highly heated, *but darker*, internal matter of the Sun. The solid, incandescent particles of *carbon*—descending in streams toward the highly heated interior of the Sun to be there again vaporized by the internal heat and to again rise to the surface of the solar globe, in the process of convection and radiation indicated above, constitute, according to my hypothesis, the luminous filaments which are the distinctive features of the *penumbra* of a sunspot, the *umbra* of the "spot" being, according to my hypothesis, due to the darker although more highly heated internal matter, or nucleus, of the Sun.

Therefore the Sun, radiating portions of the finely divided carbon of its photosphere, by and through the exceedingly tenuous transmitting medium called the "luminiferous æther," is, in this connection, perfectly analogous to the highly heated carbon filament of an incandescent electric lamp, and the radiated carbon from the solar photosphere is deposited upon the surface of any celestial body capable of receiving the deposit, just as the finely divided carbon from the filament of the incandescent electric lamp is firmly deposited upon the inner surface of the glass bulb enclosing the filament. It is, therefore quite evident that the Sun is constantly radiating carbon in a state of extremely fine division and depositing this matter upon the surfaces of planetary bodies in its vicinity and capable of receiving the deposit, the rate of deposition being a decreasing function of the mean distance of said bodies; and if this be true, the planet Mercury should be, in some measure, affected in regard to its "albedo," by the deposition of carbon upon its surface, provided that the planet be not protected by an atmosphere, from the deposition of such matter, and that the deposit be properly distributed upon its surface.

Now my computation of the theoretical brightness of Mercury, by means of a photometric formula in which the magnitude, diameter and distance of the asteroid Vesta enter as standard units, shows clearly that the brightness aforesaid is very greatly in excess of that which observation indicates, a fact which demonstrates that the "albedo" of Mercury, or the ability of the surface of that planet to reflect the sunlight incident upon it, is very small.

There is no evidence that Mercury possesses an atmosphere at all comparable with that of the Earth in density, or otherwise,

but an atmospheric envelope of small density may surround that planet, and on this account as well as by reason of the greater mean distance of Mercury from the Sun, the effect of carbon radiated from the solar photosphere and deposited upon the surface of that planet must be much less than in the case of the small intra-mercurial planetary bodies which must be quite devoid of any atmosphere; but the extremely poor reflecting power of the surface of Mercury is, I think, due to such deposited matter.

The planet Venus according to a theoretical determination which I have made—the details of which cannot obviously be set forth here—is now in the state in which the Earth was about the middle of the Cambrian age, 70 millions of years ago, it being now a body with an intrinsic surface temperature of about 221° F. and its atmosphere, by reason of this considerable temperature, is highly charged with aqueous vapor which, condensing in the cooler upper regions, forms a dense cloud-envelope which constantly obscures the real surface of the planet but which, being a good reflector of the incident solar light, causes Venus to shine with the brilliant white radiance exhibited by that planet when in favorable position. On this account as well as by the protection afforded by its dense atmosphere the "albedo" of Venus is not affected by radiated solar matter.

But a little intra-mercurial planet being wholly devoid of an atmospheric envelope which would prevent the deposition of radiated solar carbon, and being, destitute of oxygen, which would cause the combustion of the deposited matter and its conversion into carbon dioxide, and also being devoid of water which, by denudation and otherwise would nullify the effects of the deposition of such non-reflecting matter; can be regarded as being similar to a metallic ball thickly coated with lamp black. Now, it is a well known fact of physics that the actinic effects of red, or even orange, light are very feeble and therefore the conclusion is inevitable that if an intra-mercurial planet be regarded as a non-reflecting body shining with a red-orange light due to the intrinsic heat of its surface matter—as seems to be the case—it cannot be photographed during a total solar eclipse until plates having such a sensitiveness that they will receive distinct impressions of the planetary body during an exposure of less than seven minutes (which time is approximately the maximum duration of totality) has been invented and until such time they must be sought by visual means.

But detection by said means must also be a matter of consider-

able difficulty because, as I have indicated on a preceding page, these bodies, although shining by their own light, pass through phases similar to those which occur in the case of planets shining wholly by reflected sunlight and as Professor Parkhurst (*Sidereal Messenger*, Vol. 6, No. 10) has found through photometric investigations upon the asteroids, the brightness of a celestial body as the latter passes from its position of full illumination and toward its greatest elongation diminishes not only by reason of the decrease of illumined area but also by a varying amount depending upon the phase, and the defect of light on the latter account may considerably exceed that caused by diminution of illumined area; and I find that the largest of the ruddy intra-mercurial bodies when in superior conjunction and therefore fully illumined (not by reflected sunlight but by the *intrinsic* luminosity due to the surface temperature) would not exceed the 4th magnitude, and that at greatest elongation, or even considerably before it, the planetary luminosity would easily descend to the 8th magnitude or even less.

Furthermore, through one-half of its orbit through inferior conjunction, from one elongation to the other, said body must be quite invisible, and it is evident that, by reason of the small inclination of the orbit to the ecliptic, the planet when in superior conjunction must generally be occulted by the Sun, and by reason of its comparatively feeble *red* light, it cannot be well seen in the coronal glow on either side of the solar disc, and therefore, another condition of visibility is that the planet should be situate at some distance from the limb of the Sun; the only position in which such planetary body can be easily detected, visually, is when it is in a limited portion of its orbit on either side of the Sun (in an arc of probably less than one-fifth of the whole orbit) and a coincidence of its presence within this limit, and a favorable total solar eclipse, must be very rare, but such coincidence, I firmly believe, took place on July 29, 1878 when Watson at Separation, Wyoming, and Swift at Denver, Colorado, according to their firm and explicit statements, clearly saw peculiar, *red* celestial bodies, in the vicinity of the Sun.

Since the smaller intra-mercurial planets nearer the Sun are always in a much less favorable position as regards visibility, it is not surprising that none of the bodies seen by these skilled observers aforesaid have been visually detected during any favorable solar eclipse which has occurred since the memorable one on July 29, 1878; during some future total solar eclipse one, or more of these intra-mercurial planetoids may be detected *visually* by competent observers.

I think that the positive testimony of Watson and Swift in this matter is, yet, of great weight, and that the now, quite generally accepted conclusion of astronomers of eminence, that there can be no intra-mercurial planet having a diameter of 100 miles or even less—has been founded upon insufficient premises or, to say the least, is premature.

But visual observations and photographic impressions do not furnish the sole evidence by which the existence of such planetary bodies can be found. As every student of theoretical astronomy well knows, the perturbative effect due to the mass of a neighboring celestial body must indicate the existence of such body no matter whether the latter can be detected visually or can leave its impress upon the photographic plate, and it is well known to astronomers that the motion of the "perihelion" of the planet Mercury is such that there is a progressive movement of the perihelion in respect to heliocentric longitude that is not accounted for by the operation of the force of gravity exerted by the known members of the solar system.

Now, a computation which I have just completed—the details of which cannot be set forth here—demonstrates clearly, I think, that intra-mercurial planetary bodies, the density of each of which is practically the same as that of the planet Mercury, (and that their density is, practically, the same as that of the planet aforesaid, I think an inspection of the known planetary densities will indicate to be a well warranted assumption) having diameters of 700 miles, 600 miles and 460 miles and respective mean distances of 0.2145, 0.1237 and 0.0713 must cause, by their perturbative or gravitative effect a progressive motion of the longitude of the perihelion of the planet Mercury, amounting to $0''.43 +$ per annum or $43'' +$ per century in excess of the motion due to the perturbative action of the known members of the solar system. (TO BE CONTINUED.)

HONORS TO DR. LEWIS SWIFT.

W. W. PAYNE.

Our own countrymen are not generally informed of the honors that belong to earnest and industrious workers in our midst, until foreigners have known and measured the merit they have earned by some public recognition, like the award of a medal which tokens everywhere marked ability worthy of general

PLATE V.

THE JACKSON GWILT GIFT.

Awarded to Dr. Lewis Swift, by the Royal Astronomical Society, 1897.

recognition. This has been true of a considerable number of American astronomers including Professors Barnard and Swift, each of whom have been very recently so honored as has been reported in the pages of this publication.

In awarding the *Jackson-Gwilt Gift* to Dr. Swift, represented by the plate accompanying this note, Dr. Wm. Huggins, Foreign Secretary of the Royal Astronomical Society of England, wrote him as follows:

"I have the great pleasure to inform you that the council of this society has awarded to you the *Jackson-Gwilt Gift*, for your discovery of comets and for your other astronomical work. The gift consists of the interest on the invested capital, and a bronze medal. The interest amounts to $121.52, for which I enclose a draft on Messrs. Brown Bros. & Co., of New York. The medal I have placed in the hands of Professor Barnard who is now in this country. He has promised to convey it to you. I may say that this is the first time that the Jackson-Gwilt gift has been awarded. The president and council desire me to convey to you their best wishes for your future happiness and for your continued astronomical success. Permit me to add the expression of my personal congratulations and of my good wishes. I have the honor to remain faithfully yours."

The Herschel medal, which accompanied the letter, is of bronze, bearing on one side the inscription "William Herschel, MDCCXXXVIII—MDCCCXXII," surrounding a bas-relief of the great astronomer. On the reverse side is a graceful female figure supporting a globe and surrounded by the planetary system, with the inscription "Royal Astronomical Society, Jackson-Gwilt Gift." On the rim of the medal is inscribed "Lewis Swift, 1897."

Professor Swift has discovered nearly one thousand nebulæ and comets, and his discoveries in this line have been exceeded by those of Herschel, who found about fifteen hundred. Nine medals and two cash prizes have been awarded to him for his discoveries. We hope to publish a fuller account of Dr. Swift's Astronomical work in the near future.

HEAVENS FOR JUNE.

MARY PROCTOR.

The Great Bear (*Ursa Major*) occupies the greater part of the upper sky from west to north except a small space occupied by the Hunting Dogs (*Canes Venatici*). In the northwest are the Pointers, and due north, low down, is Cassiopeia

and somewhat toward the east, we find the constellation of Cepheus. The Camelopard is in the west of north. The Charioteer (*Auriga*) is low down in the northwest, whilst Castor and Pollux in the constellation of the Twins (*Gemini*) are nearing the western horizon. Nearly due west is the Crab (*Cancer*) the Sea Serpent (*Hydra*) being south of it, stretching its long body from the western to the southern horizon. Between the western horizon and the point overhead, are the constellations of the Lion (*Leo*) and *Coma* Berenices. On the Serpent's back we find the Crow (*Corvus*) and the Cup (*Crater*) and above these constellations, extending midway between the point overhead and the southern horizon is the Virgin (*Virgo*). Above the Virgin and nearly overhead, we see the Herdsman (Boötes). East of Boötes, are the constellations of *Corona Borealis*, *Hercules*, and on the eastern horizon the Eagle (Aquila) with its leading brilliant Altair. Northeast are the constellations of the Swan (Cygnus) and the Harp (Lyra), whilst (*Draco*) the Dragon, coils between the Great Bear and the Little Bear, midway between the point overhead and the northern horizon. Low down in the south is the Centaur (*Centaurus*), bearing on his spear the Wolf (*Lupus*). South of Hercules, is *Serpens*, the Serpent, and Ophiuchus, the Serpent-Holder. South of Ophiuchus, are the constellations (*Libra*) the Scales, and (*Scorpio*) the Scorpion, whilst (*Sagittarius*) the Archer, is rising due east.

Libra, the Balance.

Libra, the Balance is east of the zodiacal constellation Virgo. Virgo, was the goddess of justice, and Libra, the scales, which she is usually represented as holding in her left hand, are the appropriate emblem of her office. When the Sun enters the sign Libra, the days and nights are equal all over the world, readily suggesting the idea of a balance. Milton in "Paradise Lost" suggests another origin for the constellation of the Balance in the account of Gabriel's discovery of Satan in Paradise.

> ". . . Now dreadful deeds
> Might have ensued, nor only paradise
> In this commotion, but the starry cope
> Of heaven, perhaps, or all the elements
> At least had gone to wrack, disturbed and torn
> With violence of this conflict, had not soon
> The Eternal, to prevent such horrid fray
> Hung forth in heaven his golden scales, yet seen
> Betwixt Astrea and the Scorpion sign."

According to Virgil, the ancient husbandmen, were wont to regard this sign as indicating the proper time for sowing their winter grain. The Greeks declare that the Balance was placed among the stars to perpetuate the memory of Mochus, the inventor of weights and measures.

Libra contains about 180 stars, including two of the second magnitude, two of the third, and twelve of the fourth. Its mean declination is 8° south, and its mean right ascension 226°. Its center therefore is on the meridian about the 22d of June. It may be easily traced among the constellations, as it has four principal stars, forming a quadrilateral figure, lying northeast and southwest, and having its upper and lower corners nearly in a line running north and south. The two stars forming the northern scale, are situated about 7° apart, on the northeast side of the square. The two stars in the southern scale, are situated about 6° apart, forming the southwest side of the square. On referring to map VI of "*Half Hours with the Stars*," it will be found that Alpha in Libra, Alpha in

Scorpio and Alpha in Virgo, are nearly in a direct line with each other. This is a useful guide when there is any difficulty in locating Libra, which is an insignificant constellation, not having any leading brilliant to attract notice.

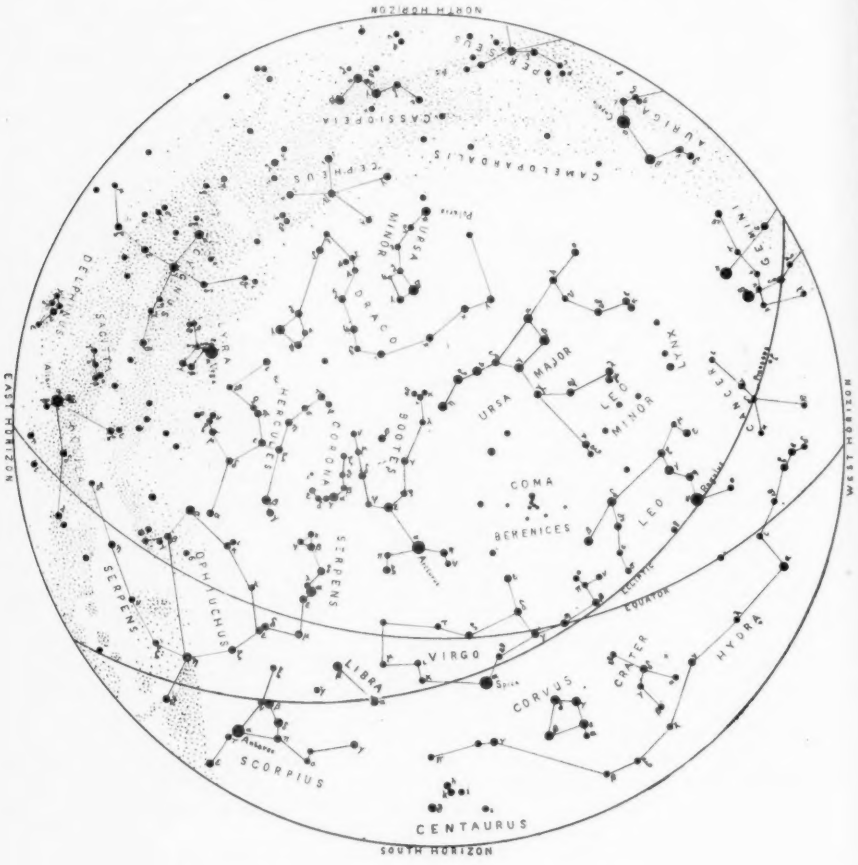
Beta Libræ.

Beta Libræ, is a beautiful light-green star when seen with the unaided eye, but the telescope shows it to be a wide double, pale emerald and light blue. The colors of the stars visible to the naked eye are faint and pale compared with those disclosed by the telescope.

Why are the Stars Colored?

The colors of the stars are due to the vaporous envelopes surrounding them. In Beta Libræ light shines through vapors of an emerald hue, and comes out tinged with emerald. The colors are real, just as the colors of red and green railway signals are real. Here we have lights which are colored, but we know that the light is really white and only appears colored because it shines through red or green glass. "Of course we know that the colored stars are not shining through any substance resembling glass. But since it has been ascertained that the light of every star in the heavens (at least every star yet tested) shines through vapors which must to some degree modify its color, the question is naturally suggested that in the case of very marked colors of certain double stars the real cause of the color is to be found in the nature of the vaporous envelope. When we examine the light of a star through a series of properly arranged prisms of glass, we get a rainbow-tinted streak of light, as in the case of the Sun, only very much fainter. Also, precisely as in the case of the Sun, the star's rainbow-tinted streak —or *spectrum*, as it is called—is crossed by a multitude of dark lines, which we know to be due to the presence of a number of vapors in the atmosphere of the star. Here I used the word atmosphere, but nothing is meant resembling our own air. Every one of the stars has an amazingly complex atmosphere of glowing vapors, so intensely hot that such substances as iron, copper and zinc are not merely melted but turned into vapor. Now, all stars are not alike as respects these vaporous envelopes. Some have substances in their atmospheres which others have not. And, again, some have apparently a much greater proportion of some substances than of others. Accordingly the dark lines across their spectra are differently arranged. Some have many dark lines in the red part of the rainbow-colored streak, so as in fact to have a great part of the red light cut off, and to shine therefore with a superabundance of the green, yellow and blue. Such stars have a greenish light. (*Beta Libræ*, is an instance). Others have most of their lines in the blue part of the rainbow-tinted streak, and so shine with an orange light. And of course it happens in many instances that the dark lines are spread with tolerable uniformity over the whole length, or the greater part, of the rainbow-tinted streak. By this method of observation, we have a means of answering the question, as to whether the colors of the stars are inherent or caused by the absorbing action of the vaporous envelopes surrounding them. The process has been applied very successfully to a beautiful double star called Albireo, or Beta Cygni. This star is seen, even with a small telescope, to be double, and one of the stars, the brightest, is orange, while the other is of a beautiful blue color. Now, when Dr. Huggins, the eminent spectroscopist, examined the spectra of these two stars, he found that whereas in the case of the orange star there are several strong dark lines in the blue part of the rainbow-tinted streak, in the case of the blue star, there is quite a cloud of fine lines in the red

and orange portions. Hence we learn that the two stars owe their color to the nature of their vaporous envelopes. Each star glows in reality with a white light but the white light has in one case to pass through vapors of a somewhat ruddy hue (because absorbing blue light) and therefore this star looks ruddy,



THE CONSTELLATIONS AT 9 P. M., JUNE, 1897.

while the light of the other star shines through bluish vapors, and therefore this star looks blue. We do not yet know how it chances that the vaporous envelopes of these stars, and of other pairs of stars, differ in this way. Perhaps we shall never know. It is, however, an important gain to our knowledge to have ascertained that the colors of the double stars are not inherent, but that these stars are, as it were, celestial signal lamps, shining through colored matter. (*Expanse of Heavens*, p. 223-225. By R. A. Proctor.)

A Double Star in Libra.

The star ε^1 and ε^2 Libra form a wide double, perhaps just separable by the unaided eye in very favorable weather. The larger component is of the third, the smaller of the sixth magnitude, the former yellow, the latter light grey. Here are two magnificent suns slowly revolving each around the other, and animated by movements in the same direction through the sky. Their distance from us is so great that although they are separated from each other by an enormous distance, yet to the unaided eye they appear as one, and we require the aid of a powerful telescope to part them. Double stars are usually termed binaries. Many of the periods of revolution are hundreds of years in length, whilst a few have a period less than a year.

A Variable Star.

Delta Libræ is a variable star with a period of 2⅓ days. During twelve hours it varies from the fifth to the sixth magnitude. Variables are stars which change in brightness, and their periods vary. Some, as in the case of Mira, in the constellation Cetus have a period of eleven months, the time required by this star to pass through one complete cycle of change; whilst a little variable star lately discovered by Dr. Chandler in the constellation of Pegasus, varies so rapidly that it may be fairly said to wink. Two or three times in the course of a single night this curious star can be seen to fade and then brighten like a signal light. For about two and three quarters hours it gets fainter and fainter; then comes a change and then at the end of two and three-quarter hours more it is as bright as at the beginning.

Cluster of Stars.

Just about 8½° from *Alpha* Serpentis, on a line with Beta Corvi, is a fine compressed cluster of very small stars, No. 5 of Messier's Catalogue. "It is scarcely resolvable in a three-inch achromatic, and merely appears like a nebula, brightening conspicuously toward the center." (*Hours with a three-inch Telescope*, p. 104. Capt. Wm. Noble.). The cluster is more than 7′ or 8′ in diameter; "A noble mass," says Smyth, "refreshing to the senses after searching for faint objects.

Constellation of Hercules.

We now come to the constellation of Hercules, which appears head downwards in the old maps, between the constellations of the Northern Crown (*Corona Borealis*) and the Lyre (*Lyra*). Alpha, in the head, is close by Alpha in the head of Ophiuchus on the south whilst the foot of Hercules is represented as resting upon the head of the Dragon (*Draco*) on the north. It is therefore bounded by Draco on the north, Lyra on the east, Ophiuchus, or the Serpent-Bearer on the South, and the Serpent and the Crown on the west. It contains 451 stars, including one of the second, nine of third magnitudes and nineteen of the fourth.

This constellation is intended to immortalize the name of Hercules, the Theban, celebrated for his brave deeds and invincible prowess. After his death Hercules was carried up to heaven in a chariot drawn by four horses.

. . . "Almighty Jove
In his swift car his honored offspring drove;
High o'er the hollow clouds the coursers fly,
And lodge the hero in the starry sky."

LEADING BRILLIANT, RAS ALGETHI.

The leading star in this constellation is *Ras Algethi*, (*Alpha*) marking the head of Hercules, a star about 25° southeast of Corona Borealis. "It is a splendid double. *A*, 3½, orange; *B*, 5½, emerald or bluish green; *D*, 4.7″. Smyth calls this a lovely object, one of the finest in the heavens." (The Amateur Telescopists Handbook, p. 130. Frank M. Gibson.)

The companion stars are small, and require a good telescope to be well seen. Ras Algethi is a variable, changing from magnitude 3 to magnitude 3½ in a period of 66⅔ days.

OTHER OBJECTS OF INTEREST.

The star *p Herculis* is a close double. The components are 3″.7 apart, the larger being of the fourth magnitude, the smaller of the fifth. The color of the larger star is bluish-white, the smaller one pale emerald.

Delta Herculis is a wide and easy double—a beautiful object. It has an eighth magnitude companion, at a distance of 19.5″. The larger star is of the fourth magnitude, and its color is greenish-white, whilst the companion star is grape-red.

There are two planetary nebulæ in this constellation, but only one of these is at all within the reach of a three-inch telescope and neither, can be found with certainty save in one equatorially mounted.

FAMOUS CLUSTER IN HERCULES.

One-third of the way from (Eta) η to (Zeta) ζ, is the famous cluster known as 13 Messier. It is one of the most magnificent objects in the heavens, with a blaze of light towards the center, and sprays of stars reaching out from it in all directions like the tendrils of a vine. It was discovered by Halley, and is sometimes called Halley's nebula. It is visible to the unaided eye, as a small misty, cloud-like object, but when seen through a telescope it reveals a scene of glory calculated to inspire a feeling of surprise in the mind of the observer. "Perhaps no one ever saw it for the first time through a telescope without uttering a shout of wonder." It requires a very powerful telescope completely to resolve this fine nebula, but the outlying streamers may be resolved with a good 3-inch telescope. Sir W. Herschel considered that the number of stars composing this wonderful object are at least 14,000. The cluster is close to the Northern Crown and in a line between the crown and the brilliant Vega.

CLUSTER SEEN WITH AN OPERA-GLASS.

"While an opera-glass will only show it as a faint and minute speck, lying nearly between two little stars, it is nevertheless well worth looking for, on account of the great renown of this wonderful aggregation of stars. It is roughly spherical in shape though there are many straggling stars around it evidently connected with the cluster. In short, it is *a ball of suns*. The reader should not mistake what that implies, however. These suns, though truly solar bodies, are probably very much smaller than our Sun. Mr. Gore has computed their average diameter to be forty-five thousand miles, and the distance separating each from the next to be 9,000,000,000 miles. . . . . If you have a field-glass, by all means try it upon 13 M. It will give you a more satisfactory view than an opera-glass is capable of doing, and will magnify the cluster so there can be no possibility of mistaking it for a star." (*Astronomy with an Opera-Glass*, pp. 47-49. Garrett P. Serviss).

"Apex of the Sun's Way."

The constellation of Hercules is of special interest because it has been shown, that the Sun is now moving towards a point in this group of stars, having a right ascension of about 267° and a declination of about + 31°. This point is known as the "apex of the Sun's way." (*General Astronomy*, p. 460. C. A. Young).

"The great problem at Mount Hamilton today is to calculate the rate of speed at which the solar system is moving through space. According to some authorities, the rate is sixteen miles a second. The more one considers these celestial journeys the stranger seem the adventures of the Sun and his attendant worlds in their stupendous journey through space. The journey is an actual one, for the Sun is really carrying us towards the northern quarter of the firmament, at least five hundred million miles every year. A railroad train does not more surely whirl us to our destination than by this great solar migration, we are swept through the abyss of the heavens towards the constellation Hercules, only in one case the rate of speed is more accurately ascertained than in the other. The wildest imaginings of the eastern fortune-tellers with their magic horses and enchanted carpets seem spiritless in comparison with what science has to tell us of the wonderful journey in which we are all unconsciously engaged. Who would not wish to see with an all-seeing eye, the caravan of worlds on its endless journey? Always gathering new material from the realms of space, adding comets and meteor-swarms to its domain, the Sun sweeps on, and the obedient planets follow but whither they are going and how it will all end, science cannot tell!"

The Northern Crown.

The constellation of the Northern Crown is a very satisfactory group, because the eye at once recognizes its resemblance to the object it is supposed to represent. It is situated directly north of the Serpent's head, between Boötes on the west and Hercules on the east. The constellation contains 87 stars, of which only six are conspicuous. Its centre is on the meridian about the last of June and the first of July.

This beautiful little cluster of stars is said to be the crown presented by Bacchus to Ariadne, the daughter of Minos, second king of Crete. According to the legend, Theseus, king of Athens, was rescued from the celebrated labyrinth of Crete by Ariadne, who furnished him with a clue of thread. He afterwards deserted her when he arrived at the island of Naxos. Ariadne was so disconsolate at being abandoned by Theseus, that, as some say, she hanged herself but Plutarch gives a more cheerful ending to the legend. According to his statement she lived many years, after, and was espoused to Bacchus, who gave her a crown of seven stars, which after her death was placed among the stars:

"Near to Boötes the bright crown is viewed
And shines with stars of different magnitude
Or placed in front among the rest displays
A vigorous light, and darts surprising rays
This shone, since Theseus first his faith betrayed
The monument of the forsaken maid."

Alphecca, the Leading Brilliant.

Alphecca, of the 3d magnitude, is the leading brilliant and middle star of the crown and about 11° E of Mirac, in Boötes. It is easily found, on account of its

position and brilliancy. It has a distant companion star of the eighth magnitude, Alphecca being of the second. Alphecca (*Alpha*) is of a dazzling white hue, whilst the component star is pale violet.

R CORONÆ.

R Coronæ was discovered by Pigott in 1795. "Ordinarily of the sixth magnitude, it occasionally drops out of sight with small telescopes, and after lingering near the thirteenth magnitude for many months, slowly regains its lost light. But its phases at times cease wholly, as during the seven years 1817-24, at others the phases are ill-marked. Thus, at the minimum observed by Sawyer, October 13th, 1885, the star was still of 7.4 magnitude. It shows no decided peculiarity either of color or spectrum." (*System of the Stars*, p. 120.)

U CORONÆ. (ALGOL VARIABLE).

"*U Coronae* was discovered by Winnecke in 1869. Its period is 3 days, 10 hours, 51 minutes and 15 seconds. It varies from the 7.6 magnitude to the 8.8 magnitude in 9 hours, 42 minutes." "It appears to be slightly variable independently of its systematic changes. The disturbances of its period have been studied by Mr. Chandler." (*System of the Stars*, pp. 136-141).

T CORONÆ.

In May 12th, 1866, a star called T Coronæ, blazed forth suddenly, equalling Alphecca in magnitude. After it was discovered it declined in brightness, and had sunk below the 8th magnitude. An opera-glass now shows it as a star of the 9th magnitude. The star is a degree south of Epsilon, and is known as the famous "Blaze Star."

Miss Agnes Clerke, gives its history as follows: "On May 12th, 1866, Mr. John Birmingham, of Millbrook, near Tuam in Ireland, was amazed to perceive an unfamiliar star of the second magnitude shining in the constellation of the Northern Crowa. On May 16, the application of Dr. Huggin's spectroscope showed the object to be wrapt in a mantle of blazing hydrogen. Five bright lines (three of them due to hydrogen) stood out from a range of continuous light broken up into zones by flutings of strong absorption. The incandescence of the star was hence largely atmospheric and for the rest, from the rapid rate at which it fell away, could have been only "skin-deep." That the compound nature of its spectrum testified truly to an immense diffusion of vaporous material in its neighborhood, was certified by Dr. Huggin's visual observation of a singular glow round the star on May 16th and 17th. Although its light decreased by a daily half magnitude and its color changed from white to orange, no alteration took place in the character of the spectrum. The bright rays, however, faded somewhat less promptly than the continuous light.

The visibility of the object to the unaided eye lasted only eight days, and already in the beginning of June, it had sunk to the 9th magnitude. Its slow subsequent decline was interrupted by fluctuations, thought by Schmidt to be periodical in about ninety-four days. When observed by Vogel, March 28th, 1878, it was of the tenth magnitude, and gave an ordinary stellar spectrum. Its leap upward to the second magnitude, involving a *thousandfold* gain of light, was accomplished with extraordinary suddenness. Two hours and a half previously to Birmingham's discovery, Schmidt surveyed at Athens the constellation in which the blaze was to occur, and noticed nothing unusual. He was certain the star could not have been as bright as the fifth magnitude. The name of "T Coronæ" was bestowed upon it in conformity with Argelander's system of

nomenclature, by which the variables in each constellation are designated, in the order of their discovery, by the Roman capital letters from R onward." (*System of the Stars*, pp. 99, 100).

SUNS IN FLAMES.

When a star suddenly blazes out in lustre, as in the case of T Coronæ, it means a catastrophe disastrous probably to the system of worlds, which may be circling around that star. Imagine if the Sun, which rules over the planetary system to which we belong were suddenly to blaze out for a time with several hundred times its usual lustre, what would be the result? "The creatures on the side of the Earth turned towards it at the time would be destroyed in an instant. Those on the dark or night hemisphere would not have to wait for their turn till the Earth, by rotating, carried them into view of the destroying Sun. In much briefer space the effect of his new fires would be felt all over the Earth's surface. The heavens would be dissolved and the elements would melt with fervent heat." (*Myths and Marvels of Astronomy*, p. 161, by Richard A. Proctor).

PLANET NOTES FOR JUNE.

H. C. WILSON.

Mercury will be at greatest elongation west from the Sun June 15, and will therefore be visible in the morning twilight about that time. Mercury and Neptune will be in conjunction June 29.

Venus will be at her greatest brilliancy on June 3. She is "morning star" shining in the east with a brightness far exceeding that of any of the stars. The Moon and Venus will be in conjunction June 25.

Mars will be too low in the west for good observations in June. The motion of this planet with reference to the stars Castor and Pollux has been very noticeable during the past month. In June Mars will continue his eastward course among the stars, passing from the Praesepe cluster in Cancer almost to Regulus in Leo.

Jupiter will be pretty well down toward the west horizon but may be observed in the evening twilight. His eastward motion begins now to be very evident with reference to the star Regulus, which is to be seen a few degrees to the west of the planet. The equatorial belt seems to have a little more color this year than usual. The "Great Red Spot" is still in place but is very dim and difficult to outline. Its location is indicated very plainly by the great notch in the broad red belt to the north of the spot. This "notch" is a far more conspicuous feature than the spot and equally permanent in form and position. Jupiter will be in conjunction with the Moon shortly after midnight, June 6.

Saturn and *Uranus* are in the constellation Libra visible toward the southeast in the evening. Saturn shines with the light of a bright first magnitude star and is of a golden yellow color. Uranus is not visible to the unaided eye, but a small telescope will show it as a small dull green disk with no definite markings. On June 18 the two planets will be in conjunction, Uranus being 2° 3′ or four diameters of the Moon, due south from Saturn.

Neptune is within the bright glow from the Sun and so cannot be seen.

The *Sun* will be at the summer solstice June 20. Sunspots are few and small, but in the early part of May one quite prominent spot was visible. It was photographed at Goodsell Observatory on May 3, 4, 6 and 7.

Jupiter's Satellites for June.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

III.

II.

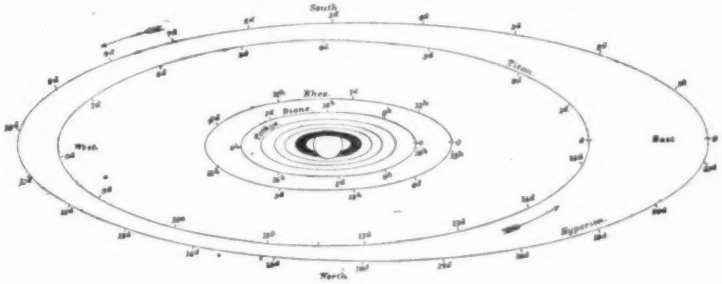
IV.

Configurations 8h for an Inverting Telescope.

Day.	West.	East.
1	·4	○ 2· 1· 3·
2	·4 2· ·1	○ 3·
3	·4 3·	○ ·2 1·
4	3· ·4 ·1	○ 2·
5	○ 1· ·3 2·	○ ·4●
6	·2	○ ·3 ·1 ·4
7	1·	○ ·2 ·3 ·4
8		○ 2· ·1 3· ·4
9	2· ·1	○ 3· ·4
10	3·	○ 1· 4· ·2●
11	3· ·1	○ 2· 4·
12	○ 1· ·3 2·	○ 4·
13	·2	○ ·1 4· ·3●
14	4· 1·	○ ·2 ·3
15	4·	○ ·1 ·2 3·
16	4· 2· 1·	○ 3·
17	4· 3· ·2	○ 1·
18	·4 3· ·1	○ ·2
19	·4 ·3 2·	○ 1·
20	·4 ·2 ·3	○ ·1●
21	·4 1·	○ ·2 ·3
22		○ ·4 ·1 2· ·3
23	2· 1·	○ 3· ·4
24	·23·	○ 1· ·4
25	3· ·1	○ ·2 ·4
26	○ 2· ·3	○ 1· ·4
27	·2 ·3 ·1	○ 4·
28	○ 1·	○ ·2 ·3 4·
29		○ ·1 2· 4· ·3
30	2· 1·	○ 4· 3·

Saturn's Satellites.

[E = at east elongation; I = at inferior conjunction (south of planet); W = at west elongation; S = at superior conjunction (north of planet].



I. MIMAS.

Period 0^d $22^h.6$

June	3	2.4	A. M.	W
	4	1 0	"	W
	4	11.6	P. M.	W
	5	10.2	"	W
	6	8.8	"	W
	7	7.4	"	W
	12	1.2	A. M.	E
	12	11.8	P. M.	E
	13	10.4	"	E
	14	9.0	"	E
	15	7.7	"	E
	20	1.4	A. M.	W
	20	12.0	MIDN.	W
	21	10.7	P. M.	W
	22	9.3	"	W
	23	7.9	"	W
	29	12.3	A. M.	E
	29	10.9	P. M.	E
	30	9.5	"	E

II. ENCELADUS.

Period 1^d $8^h.9$

June	2	2.6	A. M.	E
	3	11.5	"	E
	4	8.3	P. M.	E
	6	5.2	A. M.	E
	7	2.1	P. M.	E
	8	11.0	"	E
	10	7.9	A. M.	E
	11	4.7	P. M.	E
	13	1.6	A. M.	E
	14	10.5	"	E
	15	7.4	P. M.	E
	17	4.2	A. M.	E
	18	1.1	P. M.	E
	19	10.0	P. M.	E
	21	6.9	A. M.	E
	22	3.8	P. M.	E
	24	12.6	A. M.	E

II. ENCELADUS CON.

Period 1^d $8^h.9$

June	25	9.5	A. M.	E
	26	6.4	P. M.	E
	28	3.3	A. M.	E
	29	12.2	P. M.	E
	30	9.0	"	E

III. TETHYS.

Period 1^d $21^h.3$

June	2	2.3	A. M.	E
	3	11.6	P. M.	E
	5	8.8	"	E
	7	6.1	"	E
	9	3.4	"	E
	11	12.7	"	E
	13	10.0	A. M.	E
	15	7.3	"	E
	17	4.6	"	E
	19	1.9	"	E
	20	11.2	P. M.	E
	22	8.6	"	E
	24	5.8	"	E
	26	3.1	"	E
	28	12.4	"	E
	30	9.7	A. M.	E

IV. DIONE.

Period 2^d $17^h.7$

June	1	1.7	A. M.	E
	3	7.3	P. M.	E
	6	1.0	"	E
	9	6.6	A. M.	E
	12	12.3	"	E
	14	5.9	P. M.	E
	17	11.6	A. M.	E
	20	5.3	"	E
	22	10.9	P. M.	E
	25	4.6	"	E

IV. DIONE CON.

Period 21^d $7^h.6$

June	28	10.2	A. M.	E
	31	3.9	"	E

V. RHEA.

Period 4^d $12^h.5$

June	2	10.4	P. M.	E
	7	10 8	A. M.	E
	11	11.1	P. M.	E
	16	11.4	A. M.	E
	20	11.8	P. M.	E
	25	12.1	"	E
	30	12.5	A. M.	E

VI. TITAN.

Period 15^d $23^h.3$

June	1	10.2	P. M.	S
	5	7.3	"	E
	9	4.2	"	I
	13	8.2	"	W
	17	7.9	"	S
	21	5.0	"	E
	25	1.8	"	I
	29	5.9	"	W

VII. HYPERION.

Period 21^d $7^h.6$

June	1	10.7	P. M.	I
	6	5.5	"	W
	11	11.0	A. M.	S
	17	10 3	"	E
	23	2.4	"	I
	27	9.1	P. M.	W

VIII. JAPETUS.

Period 19^d $22^h.1$

May	19	5.0	P. M.	I
June	9	1.9	"	W
	28	11.4	"	S
July	19	4.2	A. M.	E

Phenomena of Jupiter's Satellites.

[In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of satellite; Sh., transit of shadow; * visible at Washington.]

Central Standard Time.

		h	m					h	m			
June	1	9	30	P. M.	II	Tr. In.	June	14	7	47 P. M.	IV	Sh. Eg.
	3	9	49	"	II	Ec. Re.		17	9	52 "	II	Oc. Dis.
	4	8	50	"	I	Oc Dis.		19	7	8 "	II	Tr. Eg.
	5	7	24	"	I	Sh. In.			9	23 "	II	Sh. Eg.
		8	12	"	IV	Oc. Dis.			10	4 "	I	Tr. In.
		8	28	"	I	Tr. Eg.		21	8	1 "	I	Sh. Eg.
		9	43	"	I	Sh. Eg.		22	7	48 "	IV	Oc. Re.
	6	7	20	"	III	Oc. Re.		26	7	0 "	II	Tr. In.
		8	54	"	III	Ec. Dis.			9	12 "	II	Sh. In.
	10	7	12	"	II	Oc. Dis.			9	52 "	II	Tr. Eg.
	12	8	6	"	I	Tr In.		27	9	13 "	I	Oc. Dis.
		9	19	"	I	Sh. In.		28	7	37 "	I	Sh. In.
		10	25	"	I	Tr. Eg.			8	50 "	I	Tr. Eg.
	13	7	53	"	III	Oc. Dis.			9	55 "	I	Sh. Eg.
		8	45	"	I	Ec. Re.						

Occultations Visible at Washington.

Date 1897.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
June	1	139 Tauri	5.3	7	59	118	8	49	263	0	50
	6	43 Leonis*	6 5	13	9	153	13	46	255	0	37
	12	*b* Scorpii	5.3	13	32	66	14	30	304	0	58
	12	π Scorpii*	3.4	16	47	126	17	29	237	0	42
	17	21 Capricorni*	6.4	8	56	96	9	51	233	0	55
	17	ϑ Capricorni	5 7	11	31	118	12	17	196	0	46

* Whole occultation below the horizon of Washington.

The Moon.

	Phases.	Rises. (Local Time.) h	m		Sets. h	m	
June 8	First Quarter	12	30	P. M.	12	29	A. M.
14	Full Moon	8	16	"	4	36	"
21	Last Quarter	13	43	"	1	1	P. M.
29	New Moon	3	29	A. M.	7	58	"

Search Ephemeris for d'Arrest's Periodic Comet.

[From *Bulletin Astronomique*, January 1897.]

	R. A. h	m	s	Decl. °	'	Brightness.
June 2.5	0	42	13	+3	47.8	0.26
6.5	0	55	26	4	18.7	
10.5	1	8	27	4	46.9	0.26
14.5		21	16	5	12.2	
18.5		33	50	5	34.5	0.26
22.5		46	6	5	53.7	
26.5	1	58	6	6	9.6	0.25
30.5	2	9	47	6	22.3	
July 4.5	2	21	8	+6	31.7	0.24

VARIABLE STARS.

I. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI. 1897.

	d	h
July	1	12
	6	12
	11	11
	16	11
	28	22

ALGOL.

July	3	16
	6	12
	20	20
	26	14

λ TAURI.

July	16	16
	20	15

U CORONAE. 1897.

	d	h
July	4	10
	7	20
	14	18
	21	16
	28	13

U OPHIUCHI.

July	1	14
	2	11
	5	19
	6	15
	7	11
	8	7
	10	20

U OPHIUCHI Con. 1897.

d	h
11	16
12	12
13	8
15	21
16	17
17	13
18	9
21	18
22	14
23	10
26	18
27	14
28	11
31	19

RS SAGITTARII. 1897.

	d	h
July	1	13
	6	9
	8	19
	13	15
	18	11
	20	21
	25	17
	30	13

W DELPHINI.

July	1	17
	6	12
	11	7
	25	17

Maxima and Minima of Long Period Variables.

1897 August.

	MAXIMA.	Day
1771	R Leporis	11
2266	V Monocer	28
2478	R Lyncis	5
2691	T Canis min.	5
3477	R Leo. min.	7
3637	S Carinæ.	4
4557	S Urs. Maj.	25
4596	U Virginis	26
5338	U Bootis	10
5494	S Libræ	7
5704	RR Libræ	5
5758	X Herculis	6
5830	R Scorpii	26
5887	V Ophiuchi	3
6903	T Sagittar.	15
7085	RT Cygni	8

	MAXIMA, Con't.	Day
7242	S Aquilæ	5
7260	Z Aquilæ	20:
7450	V Aquarii	23
7560	R Vulpeculæ	13
7994	R Piscis aus.	1:
	MINIMA.	
845	R Ceti	10
1222	R Persei	29
1717	V Tauri	16
2539	R Canis min.	5:
2676	U Monocer.	17
2735	U Canis min.	8
2946	R Cancri	5:
3186	T Cancri	29
3825	R Ursæ Maj.	23
4225	X Centauri	13:

	MINIMA, Cont.	Day
4521	R Virginis	7
5095	R Centauri	6:
5157	S Bootis	3
5430	T Libræ	3
5583	X Libræ	1
6044	S Herculis	14:
6207	Z Ophiuchi	28:
6794	R Lyræ	19
6849	R Aquilæ	15
6943	T Sagittæ	10:
7106	S Vulpeculæ	23
7257	R Sagittæ	29
7404	R Microscop.	4
7431	S Delphini	21
8068	S Lacertæ	10

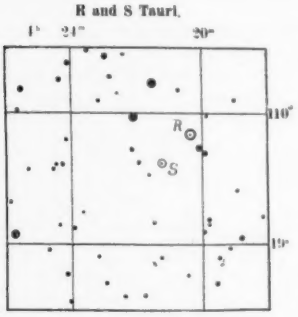
The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue. For the Algol type stars I have given all the minima which occur in the night hours in American and European longitudes, when the star is above the horizon. In the long period ephemeris all the stars are given whose periods are greater than 40 days. A colon after the date signifies doubt.

1582 S Tauri. There is a chance for some observer, using 4 inches or more aperture, to do valuable work on this star during July, August and September. The elements of the Third Catalogue are:

$$1860, \text{Feb. } 14, (240\ 0455.5) + 375.5E. \quad M - m = 70:$$

The notes to the catalogue say—"Discovered by Oudemans, 1855. Townley

thinks period is one-half that in table. The small value of M — m seems to favor this hypothesis, although there are no observations of maxima to confirm it. (Neighboring stars for identification) 11.5 mag. following 9ˢ, 1′ S; 11.5 mag. following 4ˢ, 0′.7 S; 12 mag. preceding 6ˢ, 1′ N." Townley's observations are given in Publications of Washburn Observatory, Vol. VI, part 3, page 31. They number 31 and extend from 1890, Oct. 20 to 1892, April 2. His nearer comparison stars are:



	Mag.	Co-ordinates from V. R. A.	Decl.
		ˢ	′
c	9.5	+ 16	− 5.0
d	10.2	− 7	− 4.7
e	11.2	+ 11	− 2.2
f	11 6	+ 6	− 2.2
g	12.4	+ 25	− 0.6
h	13	+ 10	− 0.2

The magnitude is 9 or 10 at maximum and fainter than 13.5 at minimum. If Townley's period is correct the star can be seen in the morning by the last of July or the first of August, while if the period is 375 days it will be invisible for several months more. The variable can be identified by the aid of the accompanying chart, which also contains R Tauri. R will be at its minimum, about 13th magnitude, in July, rising to a maximum, 7 to 9 magnitude, in December.

7792 SS Cygni. Mr. Sperra has industriously continued his morning observations of this interesting star and secured another maximum. His observations are as follows, the time being Greenwich mean:—

		Mag.			Mag.
1897, April	24.9	8.7	1897, April	28.9	9.1
	25.9	8.5	May	2.9	10.7
	26.9	8.6		5.9	11.3
	27.9	8.9			

The interval of 34 days since Mr. Sperra's last maximum, compared with the previous interval of 60 days, renders its likeness to U Geminorum complete. It will soon be in position for evening observation and should be carefully watched.

GENERAL NOTES.

The 40-Inch Lens for Yerkes Observatory arrived at Williams Bay May 19, in care of Mr. Alvan G. Clark, of Cambridge, Mass., who was accompanied by his two daughters and the foreman of his shop. From Chicago the party was provided with a special train over the Chicago and Northwestern Railway accompanied by George C. Walker, who represented the Board of Trustees of the University of Chicago. Professors Hale and Barnard met the party at the Williams Bay station and conducted them to the Yerkes Observatory buildings where others belonging to the Observatory staff had completed arrangements for the convenience of the party.

On the day following Mr. Clark put the great 40-inch lens in its cell and attached the same to the tube of telescope, the friends anxiously awaiting the first clear evening sky for the views of celestial bodies that it will disclose.

In our next number several views of the building and instruments with accompanying description will be given.

Dr. See's Work, Evolution of Stellar Systems.—We learn from a friend of Dr. See that his new work on the *Evolution of the Stellar Systems* has been received everywhere with very high favor. His mail during the last few months is said to have become enormous, and to have brought many warm congratulations from eminent authorities at home and abroad. It is said that the reception of the work in the highest and most exclusive circles of the sciences, such as the Royal Society and the great Academies of Europe, has exceeded even the most sanguine expectations of his personal friends. It is certainly a good beginning of a great work which will adequately commemorate the bold advance of Laplace one hundred years ago. The work was intended only for astronomers grounded in the higher mathematics, but we hear that a considerable demand has been pouring in on the publisher from the general public, which seems to be alive to the philosophic significance of the book. The profound truths which the author has there brought to light, and the eminently philosophical character of the discussions, ensure this treatise a place among the great works issued on this side of the ocean.

Pronunciation of Alpha Orionis.—I venture to answer the query on page 56 of the last number of POPULAR ASTRONOMY as to the proper spelling and pronunciation of the name of Alpha Orionis.

The fact that there is no real "authority" for the spelling of "Betelguese," with the u preceding the e, although it is found in some old books and star-maps which have been pretty widely used in this country. I myself gave it in the first editions of my Astronomies, through an incautious following of the spelling which I had learned as a boy from Burritt's star-atlas; and just because I fear that in this way I may have helped to propogate a rather egregious error I am now anxious to do something towards its correction.

The Arabic designation of the star is Bed-al-Jauza or Ibt-al-Jauza; i. e. the Shoulder, or the Arm-pit (according to the now uncertain vowel-pointing of the first word) of al-Jauza—the Giant. The e follows the g in the correct spelling, Betelgeuse, expressly in order to secure the sharp sound of the g: j could not be used because a German would pronounce it as y. Ideler, in his work on the names of stars, always has to use "dsch" to represent the j-sound.

The name is also spelled, Betelgeuze, and Betelgeux, by many respectable authorities.

Perhaps it may be worth while to add in this connection that the g in Rigel also has the sound of j; not that of g in "get." C. A. YOUNG.

Princeton, N. J., May 5, 1897.

Pronunciation of Star Names.—On page 56 of POPULAR ASTRONOMY for May, 1897, attention is called to a curious pronunciation of Betelgeuse, and the following statement is made: "We can but wish that Professor Howe had given the authority for these pronunciations."

The pronunciations of the names in the list to which reference is made came from several authorities, for the compiler of the list was not able to find any standard dictionary, in which the proper names of the chief stars are all given. The Imperial Dictionary, however, was most serviceable, and from it was taken the utterly barbarous pronunciation bē-tel-jūz, which appears in the list. The Century Cyclopedia of Names spells the name of this star Betelgeuze or Betelgeux and pronounces it bet-el-gĕrz'. It seems a pity that we cannot return to the original Arabic Ibt-al-jauza, the pronunciation of which any schoolboy can make a fair approximation to, without the aid of a dictionary. The writer has prepared

a larger list of pronunciations of astronomical proper names, but it would probably be useless to publish them, because there is no single authority from which they can be taken. HERBERT A. HOWE.

Mercury by Electric Light.—On the evening of April 27th I was watching for Mercury. Over the middle of the street across which I was looking, and directly in front of me, hung an arc lamp. I had seen the planet on several previous evenings and knew about where it would appear and that my line of sight would lie very close to the lamp. Consequently I was apprehensive that the current would be turned on and that the light would prevent my seeing the planet from the position I occupied. I was about to shift my position when, sure enough, the current was turned on. Exactly the contrary to what I had apprehended happened; I immediately saw Mercury in a spot where only an instant before I had been looking and did not see it. My line of sight passed not more than 3 or 4 feet below the lamp. Can it be, I thought, that the electric light has helped me to see Mercury? I resolved to test the matter on subsequent evenings but continuous cloudy weather has prevented experiments in that line. Has any reader of POPULAR ASTRONOMY had a similar experience, or can any answer the question my own experience suggested? K. M. MCCREARY.

Greensburg, Pa.

Dedication of the "Flower Observatory."—The most conspicuous event in eastern astronomical circles last month was the dedication on the afternoon of May 12, of the "Flower Observatory of the University of Pennsylvania." In response to invitations issued by the Provost and Trustees, several hundred guests assembled on the lawn in front of the Observatory proper, which is situated on a beautiful hill-top in Delaware county, on the West Chester road, about two miles west of the Philadelphia city limits.

The minor structures enclosing the delicate instruments used in the critical determinations of Professor Doolittle were inspected with evident interest; but the splendid building in which the great 18-inch refractor was poised so airily upon its tall pedestal was the centre of attraction. Though the day was cloudy the Sun occasionally smiled upon the scene, and quite a number of persons were favored with a view of the solar spectrum, under the masterful guidance of Mr. John A. Brashear, the creator of both the lens and the spectroscope.

The formal exercises were presided over by Provost Harrison, who after a few happy sentences, introduced Professor Simon Newcomb, who delivered the dedicatory address which was entitled "The Present and Future Problems of Astronomy." The audience listened with the closest attention to this Gamaliel among astronomers—in whose great reputation must be included the authorship of "Popular Astronomy," a volume to which amateurs are profoundly indebted—who spoke of the leading part which "the older astronomy" must take in future investigations.

Felicitous addresses were also made by Professor C. L. Doolittle, the Director of the Observatory, Mr. Brashear, Mr. Warner, Miss Mary Proctor and Professor Barker. It was a happy thought which thus culminated in focussing upon the platform one of the foremost of the world's astronomers, the maker of the great lens, the constructor of the superb mechanism, and the daughter of one of the most distinguished and prolific of astronomical writers, who significantly spoke of woman's work in the realm of "the noblest of the sciences"

At the close of the exercises a collation was served in the lecture room at-

tached to the handsome residence of the Director; and Mrs. Doolittle, assisted by several other University ladies, received the guests with such kindly grace as to make the social feature of the occasion delightful. The forethought of the Director, whose preparations were most efficiently seconded by his courteous associates of the Observatory, Mr. Eric Doolittle and Mr. Henry Brown Evans, made the day one long to be remembered by the visitors. Among these were Director M. B. Snyder of the Central High School Observatory and Director W. H. Collins of Haverford. The Camden Astronomical Society, of which Mr. E. E. Reed, Jr., is the efficient President, was largely represented.

Professor Doolittle, late of Lehigh, who has been warmly welcomed to Philadelphia, received a host of congratulations upon the successful completion of his fine equipment, and will now doubtless serenely go forward with his study of "latitude variation," which has already contributed so materially to this important investigation. ALDEN W. QUIMBY.

Atlas of the Uranometria Argentina.—Copies of this celestial atlas are for sale at $6.00, and can be obtained by addressing the *Astronomical Journal,* Cambridge, Mass. This well known work consists of thirteen large charts, with a fourteenth index-chart, on which are depicted accurately the positions and magnitudes of about 8,000 stars, to the seventh magnitude, between 12° north declination and the south pole. Of these nearly 6,000 are visible above the horizon in mean latitudes of the United States. It is almost indispensable to the astronomer, professional or amateur, whether employed in observation with the telescope, field or opera-glass, or naked eye; and especially so to those interested in the observation or detection of variable stars.

It will be sent, free of postage or express, on receipt of order, accompanied by remittance in postal money order or check payable to the *Astronomical Journal.*

Summer Courses in Astronomy at the University of Chicago.—The following courses in Astronomy will be given at the University of Chicago during the summer quarter, beginning July first:

1. *Theory of the determination of an elliptic orbit from three complete observations.* Integration of the differential equations for the problem of two bodies; relations between different places in the orbit; orientation of the orbit in space; corrections to be applied to the observed places and deduction of the elements of the orbit.

The theory will be applied to a special case to be selected from the list of small planets.

Prerequisite: Differential and Integral Calculus.

R. 35. Tuesday, Wednesday, Thursday, Friday, 8:30-9:30, Dr. Laves.

2. *Theory of absolute perturbations—the variation of constants.* The six elements of an elliptic orbit; difference between special and absolute perturbations; Lagrange's method of the variation of arbitrary constants; the perturbations of different orders; periodical, secular and long period inequalities; the development of the perturbative function and its derivatives for all cases where the mutual inclinations and the eccentricities are small; the perturbations of the elliptical elements which are of the first order with respect to the masses.

Prerequisite: Differential and Integral Calculus.

R. 35. Tuesday, Wednesday, Thursday, Friday, 7:30-8:30, Dr. Laves.

3. *Determination of Double Star Orbits.* The methods of Kowalsky and Klinkerfues; an application of the method of Klinkerfues to a particular star; a convenient graphical method of solving Kepler's equation accurately enough for

double star work; formulæ for improvement of elements; positions of the orbits in space with reference to the plane of the Milky Way; conclusions regarding the characteristics of double star orbits drawn from all the best known orbits. Work based on Dr. See's Evolution of Stellar Systems, vol. I.

Prerequisite: Differential and Integral Calculus.

R. 35. First Term of 6 weeks. Tuesday, Wednesday, Thursday, Friday, 9:30-10:30, Mr. Moulton.

4. *History of the Development of Astronomy.* Special attention will be paid to the causes of failures among the ancients; the value of their observations; the labors of Kepler, Copernicus, Galileo and Newton in detail with special reference to their methods; a brief review from Newton's time to the present.

R. 35. Second Term. Tuesday, Wednesday, Thursday, Friday, 9:30-10:30, Mr. Moulton.

5. *Astronomical Seminar.* The study of Le Verrier's planetary tables; to be taken with courses 1 and 2.

R. 35. Saturdays, 8:30-10:30, Dr. Laves.

U Geminorum.—In the paper on U Geminorum in the May number, on p. 17, the magnitudes on the diagram are Knott's, which do not coincide with Chandler's and Schönfeld's below the 11th magnitude. That the star never goes so low as 14 mag. seems certain from the fact that Dr. Chandler can always see it with 6½-inches of aperture.

Hours With a Three-Inch Telescope, by Captain Wm. Noble, F. R. A. S., F. R. M. S. Published by Longmans & Co., 93 Fifth Avenue, New York, and Longmans, Green & Co., London, England. The book is a very useful one. Frequent reference is made to it.

Intra-Mercurian Planets.—We are sure our readers will be interested in Mr. Corrigan's papers in late numbers of this publication, on the existence of inter-Mercurian planets. Very recently Dr. Swift, in a private letter writes as follows:

I was much interested in Prof. Corrigan's papers which I have just now read on the intra-Mercurian planet question. I see he considers their intense redness as an important fact in the discussion of their existence. I know that mine were very red, so much so as to attract immediate attention. The cause of their small round sharp disks, however, is incomprehensible to me, but they were a pretty pair. Had the objective been contracted down to two inches the explanation would have been obvious, but the whole aperture, 4½ inches, was used. His article, however, contains an error which I wish to correct. He says they were northwest of the Sun. They were southwest, or perhaps more nearly south of west. The magnifying power was 35 which at the time I supposed was 25 having from impaired hearing misunderstood the maker of the eyepiece used.

High Grade Scientific Apparatus.—Mr. Gaertner, formerly Mechanician to the Smithsonian Institution, and later of the firm of Kandler & Gaertner, of Chicago, has transferred his interests, machinery, tools, etc., to the new firm.

Mr. Regennas has had an extended experience in the manufacture of scientific instruments, including seven years in the Instrument Division of the U. S. Coast and Geodetic Survey Office.

The workshop is fitted with new and improved machinery and is located near the Fifty-Seventh Street Station of the Illinois Central—express and local suburban trains.

GAERTNER & REGENNAS.

152-154 Fifty-sixth Street, Chicago.

For Sale Very Cheap, a Brashear 8½-inch mirror and flat, two eyepieces, mount with rack and prism. The mirror is perfect being just re-silvered by Mr. Brashear. Inquire at the office of POPULAR ASTRONOMY.

Astronomical "Dishes."—Editors do not usully need borrowed spectacles with which to see the funny features of life, perhaps others also will smile at this:

"*The Story of a Speculum*," published in our May number by A. W. Quimby, was transferred bodily into one of our dailies, with full credit to "POPULAR ASTRONOMY." It was very nicely copied, except in one amusing particular. "Two glass disks" was changed into "two glass dishes." In a day or two a visitor called on Mr. Quimby to examine the speculum. He answered his many questions with pleasure, but he still seemed to be nonplussed about something. At last he said, "I don't understand what kind of glass dish this was!"